Soil Treatment Process Plan

Former ORP/Building 1 Area
Former Oakland Army Base—EDC Area
Oakland, California

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ABBREVIATIONS AND ACRONYMS

1,2,3,7,8-PeCDD	1,2,3,7,8-pentachlorodibenzo-p-dioxin
ASTM	American Society of Testing and Materials
ATS	Alternative Treatment Standard
bgs	Below ground surface
BN	Batch Number
COC	Chemical of Concern
DOCP	Dust and Odor Control Plan
DTSC	Department of Toxic Substances Control
DP	Decontamination Plan
EBMUD	East Bay Municipal Utility District
EKI	Erler and Kalinowski, Inc.
HDPE	High-density polyethylene
mg/kg	Milligrams per kilogram
mg/L	Milligrams per Liter
mL	Milliliters
MSDS	Material Safety Data Sheet
NPDES	National Pollutant Discharge Elimination System
NRP	Noise Reduction Plan
OARB	Oakland Army Base
OBRA	Oakland Base Reuse Authority
ORP	Oil Reclaiming Plant
PAMP	Perimeter Air Monitoring Plan
PCBs	Polychlorinated biphenyls
QA	Quality Assurance
QC	Quality Control
RAP	Remedial Action Plan
RCRA	Resource Conversation and Recovery Act
RDIP	Remedial Design and Implementation Plan
RMP	Risk Management Plan
SAP	Sampling and Analysis Plan
SMP	Stockpile Management Plan
SSHSP	Site-Specific Health and Safety Plan
STL	Severn Trent Laboratories
STPP	Soil Treatment Process Plan
SVOC	Semi-volatile Organic Compound
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TCLP	Toxicity Characteristic Leaching Procedure
TCTP	Traffic Control and Transportation Plan
TPH	Total petroleum hydrocarbons
TPH-d	Total petroleum hydrocarbons as diesel
TPH-g	Total petroleum hydrocarbons as gasoline
TPH-mo	Total petroleum hydrocarbons as motor oil
U.S. EPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compound

1.0 INTRODUCTION

Northgate Environmental Management, Inc. (Northgate) has prepared this Soil Treatment Process Plan (STPP) for Pacific States Environmental Contractors, Inc. (Pacific States) to describe the procedures that will be used to stabilize waste material at the former Oil Reclaiming Plant (ORP)/Building 1 Area (Site) at the former Oakland Army Base. Pacific States will implement the STPP, under contract with the Oakland Base Reuse Authority (OBRA).

Northgate has prepared the STPP in accordance with the following documents:

- *Final Remedial Action Plan* (RAP) (Erler and Kalinowski, Inc. [EKI], 2002a);
- *Draft Remedial Design and Implementation Plan for the Former ORP/Building 1 Area, Former Oakland Army Base—EDC Area* (Draft RDIP) (EKI, 2004);
- *Contract Documents for Former ORP/Building 1 Area Remediation Project (Contract Documents)* (EKI, 2005);
- *Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Wastes* (U.S. Environmental Protection Agency [U.S. EPA], 2002); and
- *Amendment 1: Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Wastes* (U.S. EPA, 2003).

The objectives of the stabilization process for Building 1 Remediation Waste are to: 1) reduce the mobility of lead and other underlying hazardous constituents, 2) neutralize acid in the waste, and 3) assure that any free liquids contained in the waste are removed and that the treated material contains less than 50 percent water content following treatment. The Building 1 Remediation Waste will be treated on site and disposed at a permitted offsite disposal facility, in accordance with the Draft RDIP (EKI, 2004) and a *Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Waste* issued by the U.S. EPA (July 2003). Figure 12 shows the project schedule, including the sequence of work planned and task durations.

1.1 Support Documents for the Remediation Process

In addition to this STPP, eight plans have been prepared to document procedures to be followed during the remediation process. These additional plans have been prepared to address aspects of the remediation process that affect how fieldwork will be performed and how the Site will be managed.

These plans include:

- ***Dust and Odor Control Plan (DOCP)*****—**The DOCP has been prepared to address control of dusts and odors during demolition, excavation, stockpiling, and soil treatment and loading activities.
- ***Perimeter Air Monitoring Plan (PAMP)*****—**The PAMP has been prepared to address monitoring of hydrogen sulfide, airborne lead, and airborne dust at the perimeter of the Site during demolition, excavation, stockpiling, soil treatment and loading, and construction activities.
- ***Stockpile Management Plan (SMP)*****—**The SMP has been prepared to address how stockpiles of soil and waste will be managed throughout the entire remediation process.
- ***Site-Specific Health and Safety Plan (SSHSP)*****—**The SSHSP has been prepared to address health and safety information and guidelines for all activities to be conducted during the remediation process.
- ***Traffic Control and Transportation Plan (TCTP)*****—**The TCTP has been prepared to address safe practices for on-site handling, loading, and off-site transportation of materials (including Building 1 Remediation Waste, Stained and Oily Soil, and Overburden Soil) that is not acceptable for re-use on site. In addition, the TCTP specifies traffic controls measures that will be implemented, as required, during hazardous waste remediation, demolition, and construction activities to be conducted at the Site
- ***Decontamination Plan (DP)*****—**The DP has been prepared to address the procedures for decontamination of equipment, personnel, and transportation vehicles, as well as the management of wastes generated during decontamination activities.
- ***Storm Water Pollution Prevention Plan (SWPPP)*****—**The SWPPP has been prepared to address compliance with the requirements of the State Water Resources Control Board's (SWRCB) National Pollutant Discharge Elimination System (NPDES) general permit for storm water discharges resulting from construction activities.
- ***Noise Reduction Plan (NRP)*****—**The NRP has been prepared to address control of noise generated by equipment used and activities performed during the remediation process.

1.2 Background and Summary of Previous Pre-Design Investigations

The former ORP/Building 1 Area is located between Alaska Street and Bataan Avenue, and Wake Avenue and Maritime Street, as shown on Figure 1. The ORP consisted of buildings, structures, and several aboveground tanks used to recycle oil. The ORP used an acid/clay oil refining process. ORP operations generated an acidic sludge/spent clay and oily waste. A review of historical aerial photographs taken in 1931 and 1939 performed by EKI showed the ground to be stained around the former ORP building and tanks. It is thought that the staining resulted from spills from waste oil recovery operations. The area north of the ORP reportedly was used for disposal of the wastes. In 1941, the disposal area was apparently covered by the U.S. Department of Defense, Department of the Army (Army) with approximately 3 feet of clean imported fill and Building 1 was constructed. The Army has completed demolition of Building 1 to allow access for excavation and removal of contaminated soil in accordance with the RAP and Draft RDIP.

1.3 Identification of Organic Residue and Building 1 Remediation Waste

As reported in the Draft RDIP (EKI, 2004), a layer of Organic Residue with thickness varying from a few inches to approximately 2 feet is found to the north of the former ORP. The Organic Residue contains chemicals of concern (COCs) above the Remediation Goals specified in the RAP. This material can be visually characterized during excavation and is generally separable from Overburden, underlying clayey and sandy sediments, and other chemically-impacted soil that is not Organic Residue. Once excavated, that portion of the Organic Residue that exceeds the Resource Conservation and Recovery Act (RCRA) toxicity characteristics for lead (Toxicity Characteristic Leaching Procedure [TCLP] greater than 5 milligrams per liter [mg/L], D008) or the corrosivity characteristic (pH less than 2.0, D002) will be classified as Building 1 Remediation Waste, and treated as necessary. Laboratory analysis of the Organic Residue has confirmed its acidic pH and maximum total lead concentration of 17,000 milligrams per kilogram (mg/kg). Table 3 in Appendix D of the Draft RDIP (EKI, 2004) summarizes analytical results for Organic Residue samples.

The Contract Documents for the Former ORP/Building 1 Area Remediation (EKI, 2005) estimated that 10,000 tons of the Organic Residue will be managed as Building 1 Remediation Waste. However, actual quantities of Building 1 Remediation Waste may vary greatly.

The Organic Residue will be stockpiled onto the Treatment Pad with each stockpile having an approximate volume of 200cubic yards. Each stockpile will be placed on an area of approximately 45 feet by 45 feet in plan dimension. The approximate dimensions of the stockpile will be 40 feet wide by 40 feet long, and 12 feet high. The layout of the Treatment Pad provides space for seven stockpiles to be processed at a time, as shown on Figure 4.

Based on the preliminary estimate of 10,000 tons, approximately 37 stockpiles of Organic Residue will be remediated. A layer of visually impacted soil containing COCs such as total petroleum hydrocarbon (TPH) and lead (referred to as “Stained and Oily Soil”) is found beneath the former ORP structures and is adjacent to the area where Organic Residue was identified. The thickness of the Stained and Oily Soil varies from a few inches to approximately 4 feet. Only a portion of the Stained and Oily Soil appears to be contaminated with COCs at concentrations greater than Remediation Goals. Table 4 in Appendix D of the Draft RDIP (EKI, 2004) summarizes analytical results for Stained and Oily Soil samples. Based on available data, the Stained and Oily Soil is not a RCRA characteristic hazardous waste; however, such soil may be a non-RCRA hazardous waste. The pH of the Stained and Oily Soil is close to neutral.

1.4 Variance

As previously noted, the U.S. EPA (2002) issued a *Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Waste for the Building 1 Remediation Waste*, which establishes site-specific treatment requirements.

Solidification/stabilization technology will be applied to Building 1 Remediation Waste to reduce the mobility of lead and other underlying hazardous constituents that may be present. The solidification/stabilization agent will also raise the pH to more neutral levels. After treatment, the Building 1 Remediation Wastes will have a pH greater than 4, and percent moisture less than 50 percent by weight.

Lead has been selected as the indicator compound to determine adequate treatment of the Building 1 Remediation Wastes. According to the *Amendment 1: Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Wastes*; U.S. EPA, 2003, "The selected site-specific alternative treatment standard is a 77 percent reduction in leachable lead, capped by a result of 5 mg/L (or less) as measured via the Toxicity Characteristics Procedure (TCLP)"

The percent reduction will be determined by measuring the concentration of TCLP lead before and after applying solidification/stabilization technology to the Building 1 Remediation Waste. The pre-treatment and post-treatment sampling frequencies are anticipated to consist of one representative soil sample composite from a minimum of four individual samples collected from each 200 cubic yards of soil to be treated.

1.5 Analytical Methods for Pre-treatment and Post-treatment Profiling for Building 1 Remediation Waste

The following Section describes all testing and analytical methods, associated laboratory method identification numbers, reporting limits, quality assurance (QA) protocols, and requirements for performance by the laboratory, as required in the *Sampling and Analysis Plan*, Appendix B of the Draft RDIP (EKI, 2004).

1.5.1 Laboratories

For definitive-level analyses, Curtis and Tompkins, Ltd. in Berkeley, California, and Severn Trent Laboratories (STL) in Pleasanton, California, have been identified as the primary fixed-base analytical laboratory subcontractors.

Contact information for these laboratories is as follows:

Curtis and Tompkins, Ltd.
2323 Fifth Street
Berkeley, California 94710
Phone: (800) 522-1878 or (510) 486-0900
Fax: (510) 486-0532

STL San Francisco
1220 Quarry Lane
Pleasanton, California 94566
Phone: (925) 484-1919
Fax: (925) 484-1096

Definitive-level analytical services for dioxin will be subcontracted to STL in West Sacramento, California, and Eno River Labs, LLC, in Durham, North Carolina.

Contact information for these laboratories is as follows:

STL Sacramento
880 Riverside Parkway
West Sacramento, CA 95605
Phone: (916) 373-5600
Fax: (916) 372-1059

Eno River Labs, LLC
2445 South Alston Avenue
Durham, NC 27713
Phone: (919) 281-4054
Fax: (919) 281-4070

1.5.2 EPA Method SW1311—TCLP

The TCLP is designed to simulate the leaching a waste will undergo if disposed of in a sanitary landfill. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A sub-sample of a waste is extracted with the appropriate buffered acetic acid solution. The TCLP extraction will take approximately 48 hours. Testing and analysis of the TCLP extract involves identifying and quantifying chemical species using appropriate EPA Methods as noted in this STPP.

QA procedures for the TCLP extraction procedure include a method blank prepared using the same extraction procedures and analyzed in the same batch of samples as the TCLP extract.

1.5.3 EPA Method 6020—Lead by ICP/MS

ICP-MS determines elements in a solution. All matrices, including groundwater, surface water, industrial wastes, soils, sludges, and sediments, require digestion by EPA Methods SW3005A (aqueous samples), SW3050B (solid samples), or SW1311 (TCLP) prior to analysis.

The reporting limit for lead analyzed by this method is 0.25 mg/L (parts per million) for aqueous samples and 0.25 mg/kg (parts per million) for solid samples. Laboratory quality assurance/quality control (QA/QC) procedures will include an analysis of a calibration standard each day prior to sample analysis and continuing calibration checks between every 10 samples. QC samples will include analysis of method blank, laboratory control spike, and matrix spike/matrix spike duplicate samples for each batch of 20 samples analyzed. Samples will be spiked with surrogate compounds and surrogate recoveries will be used to monitor matrix effects and sample preparation.

1.5.4 American Society of Testing and Materials (ASTM) Method D2216—Soil Moisture Content

Determining soil moisture content involves transferring a moist sample to a pre-weighed container, measuring the gross weight, then placing the sample and container to dry in a pre-heated oven at 110°C ± 5°C. During the drying period, a current of dried air flows through the oven. After the drying period, the sample is removed and allowed to cool in a desiccator before weighing. The modified formula for calculating moisture, as listed below, will be used for the calculations:

$$w = [(W1 - W2)/(W1 - WC)] \times 100$$

Where: w = moisture content, percent

- W1 = weight of container and moist soil, grams;
- W2 = weight of container and oven dried soil, grams; and
- WC = weight of container, grams.

1.5.5 EPA Method SW9045—pH

EPA Method SW9045 will be used to measure pH for soil samples. The pH of the solution will be measured using either a glass electrode in combination with a reference potential or a combination electrode, and reported to the nearest 0.1 pH units.

Electrodes will be calibrated daily prior to measurement, using at least two points that bracket the expected pH of the samples and are approximately three pH units or more apart. Samples will be analyzed no later than 24 hours after sample collection.

1.6 Health and Safety Hazards

Organic Residue contains elevated concentrations of lead and has a low pH. For these reasons, site workers must follow health and safety procedures to limit dermal contact and potential inhalation of contaminated materials as specified in the SSHSP (Northgate, 2005e)

2.0 SOIL TREATMENT

Given the heterogeneous nature of the Building 1 Remediation Waste, Pacific States has selected ex-situ soil treatment on a treatment pad as the treatment method for the Site. The Building 1 Remediation Waste will be excavated, stockpiled, pre-treated including removal of debris, and mixed with a treatment reagent that is capable of achieving the alternative treatment standard (ATS) established in the U.S. EPA's variance for the Site.

2.1 Description of the Treatment Pad

Prior to excavation of Building 1 Remediation Waste, a treatment pad will be constructed in the northern portion of the Site, as shown on Figure 2. The existing ground surface of the pad site consists of a paved area, including foundation slabs of the former Building 1 and a fill area. A backhoe-mounted concrete breaker will be used to smooth the surface in the treatment pad area to remove protruding remnants of stem walls, concrete foundations, and steel rebar. Imported fill soil will be used to bring low areas up to level the pad area. The soil portions of the pad site will be stripped of vegetation and any remaining items that could damage a high-density polyethylene (HDPE) membrane, scarified to a depth of 6 inches, and track-walked to archive approximately 95 percent relative compaction. An appropriate layer of sand will be placed and track-walked above the compacted subgrade to provide for a smooth surface. A 60-millimeter HDPE membrane will be placed on the sand pad. Each roll of HDPE is 20 feet wide and will be placed with a 6- to 12-inch overlap on top of the sand bed. The seams will be welded to create an impervious barrier following procedures described in Appendix A (Installation Quality Assurance Manual) of this STPP. An 8.2-ounce Mirafi non-woven 180N™ geotextile filter fabric will be placed onto the HDPE membrane for protection against damage from the 6-inch thick aggregated base course that will be placed onto the geotextile and compacted. The aggregate base will be compacted by track walking to approximately 95 percent relative compaction. A 3-inch layer of asphalt concrete will then be placed and compacted on the base coarse, including a 12-inch high asphalt berm surrounding the entire treatment pad. The asphalt pavement will be sloped at 1 percent towards a low point as indicated on the treatment pad section details shown on Figure 4.

The dimensions of the planned treatment pad are approximately 150 by 380 feet. Figure 4 shows the layout of the treatment pad, the untreated material stockpile areas, the debris removal and mixing areas, treated material stockpile and loading zone, decontamination area, the treatment pad entry and exit points, and the pad low point. Leachate from Building 1 Remediation Waste stockpiles and potential stormwater will drain into the low point where liquid will be captured and pumped with a portable pump into a tank. The liquid will be contained in an approximate 19,000-gallon storage tank and disposed off site at an OBRA-approved facility.

Prior to disposal, water samples will be analyzed for the following, or as required by the disposal facility:

- pH by EPA Method 9045;
- Title 22 Metals by EPA Method 6020;
- Semi-volatile organic compounds (SVOCs) by EPA Method 8270C;
- Volatile organic compounds (VOCs) by EPA 8260B;
- Total petroleum hydrocarbons as gasoline (TPH-g) and as diesel (TPH-d) by EPA Method 8015 with silica gel cleanup; and
- Polychlorinated biphenyls (PCBs) and organochlorine pesticides by EPA Methods 8081A and 8082.

It is the intent of Pacific States to obtain a discharge permit and discharge the wastewater to the sanitary sewer in accordance with appropriate laws and regulations. In the event that analytical results are above permitted levels, wastewater will be transported to an approved offsite disposal facility or may be treated using a Transportable Treatment Unit (TTU) according to applicable laws and regulations. Sampling protocols will follow the requirements for waste acceptance set forth by the discharge permit or by the East Bay Municipal Utility District (EBMUD).

Storm water will run off plastic sheeting that will cover the Building 1 Remediation Waste stockpiles. Water will be contained by the asphalt pavement and surrounding asphalt berm and will accumulate at the low point. As detailed in Appendix F, the treatment pad has a net storage capacity of approximately 535,000 gallons, considering the displaced volume from seven stockpiles. This capacity is considered to be sufficient to contain precipitation during the Building 1 remediation project.

Water will be temporarily contained on the pad, until it can be characterized and disposed at an approved facility. Water will be pumped from the treatment pad to a 19,000-gallon storage tank. Specifications for the portable pump, including discharge rates, are provided in Appendix G. Gravel bags will be placed around the pump intake line to remove sediment prior to the removal of water from the pad. Water will be pumped or gravity-drained from the 19,000 gallon storage tank through a sand filter for additional removal of sediment. The filtered effluent will be stored in a 10,000-gallon tank, pending chemical analysis. Once the treated water has been found to be acceptable for discharge to the sanitary sewer, this holding tank will be removed.

The treatment pad will be visually monitored for containment breaches and will be repaired, as necessary, by hot asphalt patching in combination with spray binders. If storm water and/or leachate percolates down through the asphalt concrete to the HDPE membrane, the water/leachate will be contained by the membrane and the asphalt concrete berms at the edges of the pad. At the time of decommissioning, if any water/leachate is present in the aggregate base, it will be carefully pumped with a portable pump into the water storage tank and managed as disposal water as specified in Section 2.1 of the STPP.

At the time of decommissioning of the treatment pad, any loose soil will be scraped off the asphalt pavement and stockpiled onto a plastic sheet. One 4-composite sample will be collected from the stockpile and tested for the following:

- Lead by EPA Method 6020 in TCLP extract using TCLP Method 1311 provided in SW-846;
- pH by EPA Method 9045;
- Title 22 Metals by EPA Method 6020;
- SVOCs by EPA Method 8270C;
- VOCs by EPA Method 8260B, and
- Moisture content by ASTM Method D2216.

The stockpiled loose soil will be waste profiled and disposed at an approved landfill.

The treatment pad will be decommissioned by grinding the layer of asphalt and excavating the aggregate base. These materials will be placed as two separate stockpiles on plastic sheets. One 4-composite sample will be collected from each stockpile and tested for the following:

- Lead by EPA Method 6020 in TCLP extract using TCLP Method 1311 provided in SW-846; and
- pH by EPA Method 9045;

Depending on the analytical test results, the materials will be re-used on site or disposed of at an approved landfill. To be re-used on site, the stockpiled loose soil/material should not contain COCs above the remediation goals as shown in Table 7-11 of the RAP (EKI, 2002a) and should not be a Federal or State of California hazardous waste as stated in *Soil Reuse, Former Oakland Army Base – EDC Area, Oakland, California* (DTSC, 2004).

Geotexile fabric and HDPE liner are assumed to be non-hazardous and will be cut in sections, removed, and disposed at an approved Class III facility.

2.2 Construction Equipment

The following equipment will be utilized during the soil treatment process. Additional specifications for construction equipment are presented in Appendix C.

- ***Excavator***—A Caterpillar™ 330 excavator will be used to excavate the overburden, Building 1 Remediation Waste, and Stained and Oily soil. The excavator is approximately 37 feet long, 8 feet wide, and 11½ feet tall, and will load the trucks to move the materials to the stockpile areas.
- ***End Dump Trucks***—Ten-wheel end dump trucks (approximately 26 feet long, 9½ feet wide and 9½ feet tall) will be utilized for hauling the excavated materials on a delineated haul road to the treatment pad and stockpile areas. For placing purposes each stockpile location will be accessible through the peripheral loading zone.
- ***Front Loader***—A front loader (approximately 12 feet wide, 30 feet long, and 12 feet tall) will remain on the treatment pad during remediation operations and move the material into stockpiles and spread the batches to an 18-inch thick layer for the mixing process. An approximately 12-feet wide space will be maintained between the 200-cy batch treatment areas as shown on Figure 4.
- ***Spreader—***The Spreader utilized for reagent distribution is custom-made by the Contractor for use during soil stabilization. The technical and dimensional specifications (typically 10 feet wide, 20 feet long, and 12 feet tall) compare to a typical spreader used for agricultural purposes. Technical specifications and a photograph of the Spreader are included in Appendix C.

  Cement is loaded into the spreader by pumping from a pneumatic transport truck carrying approximately 26 tons. The spreader is equipped with a bag house to control any potential release during the transfer of cement. Once the cement is loaded onto the spreader (approximately 15 tons), it is carried over to the area where mixing of cement and soil will take place. The potential for fugitive emissions of cement dust is mitigated by two methods: 1) a curtain or skirt is placed around the vane that directs the cement down to the ground (approximately 18 inches high) to contain potential cement particulates near the back of spreader; and 2) cement application is controlled by maintaining a slow spreader travel speed. Once the cement blanket is placed on the ground surface, it resists blowing away. The above control measures will significantly reduce the potential for fugitive dust emissions during the spreading process. The effectiveness of these control measures will be continuously monitored and additional control measures will be applied, as necessary, in accordance with the Dust and Odor Control Plan. Once cement is spread, mixing operations will begin.

- ***Mixer—*** The mixer will combine the Building 1 Remediation Waste with the reagent. The mixer to be utilized is a Wirtgen America Inc. WR 2500 Super Road Reclaimer and Soil Stabilizer™, or an RS 5000 depending on the availability. The WR 2500 is a high performance, full-depth soil and base stabilizer, and is approximately 10 feet wide, 30 feet long, and 14 feet tall. The stabilizer's diesel engine powers a 96-inch-wide by 20-inch-deep cutting rotor. Material size is controlled by using hydraulically adjustable, manganese-lined breaker bars.

  Computer sensors connected to the right-front and left-rear tires control the depth of mixing. The mixing depth set by the lowest tire is the design mixing depth. The highest tire lowers the depth of mixing rotors to maintain a level mixing elevation. If the mixer is traveling over a flat surface, then the rotor depth will be the same on all corners. As described in section 2.9, debris will be removed and material larger than 4 inches will be crushed prior to mixing. This pre-treatment step will help maintain a flat surface, reducing the potential for the mixing rotors to contact the pad surface.

  The potential for release of cement is mitigated by beginning the mixing process immediately after cement is spread. In addition, a water truck is attached to the mixer during initial hydration of cement. The mixer contains an on-board computer to meter water intake.

- ***Water Truck—***The water truck assembly consists of a 4,000-gallon tank, constructed from 3/16-inch thick carbon steel with lapped seams that measures 14 feet long, 8 feet wide, and 5 feet tall, and is mounted on a 16-foot long frame assembly. The tank has a modified octagonal design for increased stability, inset front and rear panels for added strength, and quick-coupled air and hydraulic lines. The assembly contains a hydraulic drive water pump and two air-operated spray heads located on a rear- mounted spray bar. The water truck will be used as necessary to control dust and to moisten materials to hydrate the cement.

- ***Haul Trucks—***Haul trucks will be used to remove treated and other unsuitable materials off site to disposal facilities. There are a number of truck types that may be used depending on the use and trucking company. In general, these trucks have either 10 or 18 wheels and empty their loads by end dumping. The off-site haul trucks will be fitted with tarping systems to mitigate the potential for materials to be blown from the trucks during transit

2.3 Decontamination

Vehicles for on-site transportation between the base excavation and the stockpile area and treatment pad will use the haul road within the exclusion zone. The location of the haul road is shown on Figure 2. Equipment and transportation vehicles exiting the exclusion zone will be inspected and decontaminated, as necessary, at a temporary decontamination pad.

The decontamination procedures follow the protocol set forth in the DP (Northgate, 2005a) and include initial dry decontamination techniques and washing off the residual dust and soil from tires and tracks of equipment and vehicles on a decontamination pad.

A decontamination pad will be constructed on Bataan Avenue south of the treatment pad, in the general location shown on Figure 2. This facility will be constructed and operated in a manner to contain debris and wash water that is generated from the decontamination of vehicles and equipment exiting the Site. Specific construction details for the decontamination pad are provided in the DP (Northgate, 2005a).

2.4 Pre-Excavation Overburden Testing

Organic Residue. The Draft RDIP (EKI, 2004) calls for collecting 15 additional composite Overburden Soil samples to augment the available in-situ data collected during previous investigations. These composite Overburden Soil samples will be tested for dioxins, dioxin-like compounds, and other chemicals, in accordance with Appendix B, Section 4.2 of the Draft RDIP (EKI, 2004). The tests for dioxins and dioxin-like compounds require approximately 1 month to complete. If testing for dioxins and dioxin-like compounds were to wait until the Overburden Soil is excavated and stockpiled in accordance with the original construction schedule, this lengthy testing time frame would delay the project completion schedule. Therefore, 15 composite samples for analysis of dioxins and dioxin-like compounds will be collected in-situ from the Overburden Soil within the Base Excavation area prior to excavating and stockpiling the Overburden Soil. The other chemical analyses will be performed on an additional 15 composite samples collected from the Overburden Soil after it has been excavated and stockpiled, as discussed below.

The results of previous Overburden Soil sample analyses for dioxins are shown on Figure 7. The dioxin 1,2,3,7,8-pentachlorodibenzo-p-dioxin (1,2,3,7,8-PeCDD) was detected in one composite sample collected from trenches OBRA-T08 and OBRA-T10, within the Base Excavation area (Figure 7). Three previous composite samples in other locations within the Base Excavation did not detect dioxin-like compounds, as shown on Figure 7.

2.4.1 In-Situ Sampling Procedures

To select the in-situ composite Overburden Soil sampling locations for analysis of dioxins and dioxin-like compounds, the Base Excavation area will be divided into a grid with 45 discrete sampling points grouped into 15 composite sample areas (Figure 7). A discrete soil sample will be collected from each of the 45 points, and subsequently combined into 15 three-point composite samples, as discussed below. The 15 composite sampling areas each encompass approximately 600 cubic yards of Overburden Soil. The 45 individual sample points will be surveyed and marked on the ground surface before sampling begins, as discussed below. The composite soil samples will be analyzed for dioxins and furans using EPA Method 8290. The methods for collecting and compositing the in-situ Overburden Soil samples are described below.

The following describes the methods and procedures for collecting in-situ composite Overburden Soil samples. Each of the 45 sampling points shown on Figure 7 will be surveyed and marked on the ground surface of the Base Excavation area using orange paint and/or stakes and flagging. The boundaries of the three-point composite sampling areas shown on Figure 7 will be marked on the ground using orange paint. In addition, reference marks corresponding to the grid locations for each of the sample locations will be surveyed and painted approximately 10 feet outside the perimeter of the Base Excavation Area. These reference marks will be used to help identify the sampling locations associated with each area of Overburden Soil during the excavation.

A backhoe will be used to excavate an approximately 2.5-foot deep trench at each of the three sampling points within each composite sampling area (a total of 45 trenches for 15 composite samples). The trenches will be carefully excavated by taking 0.5 to 1-foot lifts with each pass of the backhoe bucket, and a California registered geologist or professional civil engineer (or a geologist working under the supervision of one of these registered professionals) will log the soil lithology in the field during trenching. Soil samples will be collected from the depth interval from 2.0 to 2.5 feet below ground surface (bgs) at each trench location. If the soil removed from the trenches is cohesive in nature and remains intact in the backhoe bucket as an undisturbed chunk of soil, samples may be collected directly from the soil in the backhoe bucket. Otherwise, soil samples will be collected directly from the sidewall of the trench within the depth interval from 2.0 to 2.5 feet bgs. Soil samples will be collected and transferred to laboratory-supplied glass jars using pre-cleaned hand tools. One 16-ounce jar of soil will be collected from each trench in the composite sampling areas and composited (3:1) for analysis of dioxins and furans using EPA Method 8290. Compositing procedures are described in Section 2.4.3.

2.4.2 Stockpile Sampling Procedures

The Overburden Soil will be excavated and placed in 10-wheel trucks and transported to the northeastern corner of the Site for stockpiling. Overburden Soil excavated from each area represented by the proposed in-situ sample locations shown on Figure 7 will be placed in temporary stockpiles in the Overburden Stockpile Area in accordance with the SMP (Northgate, 2005g). Individual stockpiles of Overburden Soil will not exceed 200 cubic yards. A soil stockpile tracking form will be completed for each Overburden Soil stockpile to provide continuous tracking of each soil stockpile from the time of excavation to its final disposition (reuse or off-site disposal), as described in the SMP. The stockpile tracking form will also allow each stockpile to be associated with the corresponding Overburden Soil analytical results.

One three-point composite soil sample per approximately 600 cubic yards of stockpiled Overburden Soil will be collected and analyzed. Each composite sample will be comprised of three discrete samples collected from the 200 cubic yards stockpiles or stockpile segments generated from the composite sampling areas shown on Figure 7. One 16-ounce jar of soil will be collected from each of the stockpiles, and used to form a three-point composite sample, as described in Section 2.4.3. The composite samples will be analyzed for the following constituents, in accordance with Section 4.2 of Appendix B of the Draft RDIP (EKI, 2004):

- Title 22 Metals by EPA Method 6020;
- Selected SVOCs by EPA Method 8270C,[1]
- TPH-d and total petroleum hydrocarbons as motor oil (TPH-mo) by EPA Method 8015M, with silica gel cleanup; and
- PCBs by EPA Method 8082A

A discrete sample for analysis of selected VOCs by EPA Method 8260B[2] will be collected from one of the stockpiles generated from each composite sampling area shown on Figure 7. The discrete sample for VOC analysis will be collected from the stockpile using En Core™ or TerraCore™ samplers (U.S. EPA Method [EPA] 5035), in accordance with American Society of Testing and Materials (ASTM) recommended procedures. For each discrete soil sample, three En Core™ or TerraCore™ samples will be collected from the stockpile, and will be frozen by the laboratory so that the hold time for VOCs will be 5 days, in accordance with the Draft RDIP (EKI, 2004).

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[1] The selected SVOCs for chemical analysis will include only those SVOCs that were identified in the RAP/RMP as COCs at the Former ORP/Building 1 Site. These SVOCs include: acenaphthene, acenaphthylene, benzo(a)-anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, and pyrene.

[2] Discrete samples for VOC analysis will be collected using En Core™ or TerraCore™ samplers by EPA Method 5035. The samples will be frozen by the laboratory upon receiving the samples such that the hold time for VOCs is 5 days. The selected VOCs for chemical analysis will include only those VOCs that were identified in the RAP/RMP as COCs at the Former ORP/Building 1 Site. These VOCs include: 1,2,3-trichloropropane, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,2-dichloropropane, acetone, benzene, carbon disulfide, carbon tetrachloride, cis-1,2-dichloroethene, ethylbenzene, isopropylbenzene (cumene), methylene chloride, methyl ethyl ketone (2-butanone), methyl isobutyl ketone, methyl tertiary butyl ether, n-propylbenzene, p-cymene (p-isopropyltoluene), sec-butylbenzene, tetrachloroethene, toluene, trichloroethene, vinyl chloride, and xylenes.

Based on review of the above data, additional testing such as TCLPs and Waste Extraction Tests ("WETs") may be required to demonstrate that the stockpiled Overburden is not Federal or State of California hazardous waste in accordance with the RAP/RMP requirements for backfill material.

2.4.3 Compositing Procedures

Overburden Soil samples (with the exception of discrete samples collected for VOC analysis) will be composited in the field using the following procedures (U.S. EPA, 1992). One 16-ounce jar of soil from each stockpile will be emptied into a pre-cleaned stainless-steel mixing bowl and thoroughly mixed using pre-cleaned, stainless-steel hand tools to form a homogeneous discrete sample. After mixing, the soil will be divided into two halves. One-half of the discrete sample will be placed into a new, laboratory-supplied glass jar and submitted to the laboratory on hold, for possible later analysis as a discrete split sample. The remaining half of the discrete sample will be placed into a second pre-cleaned mixing bowl for compositing with two other discrete soil samples (to produce a 3-point composite for 600 cubic-yards of soil); as described further below.

One-half of each of the three discrete samples to be composited will be combined in a pre-cleaned, stainless steel mixing bowl and thoroughly mixed using pre-cleaned, stainless-steel hand tools. When the soil is thoroughly mixed, it will be placed into two new, laboratory-supplied glass jars (one of the jars will be analyzed and the other jar will be saved as a back-up composite sample, in case the sample needs further analysis for waste characterization). The jars will be labeled with the composite sample number, placed in a cooler chilled to 4° C with ice, and submitted to the laboratory under chain-of-custody protocol for analysis using the methods described above.

2.5 Excavation

Initially, the excavation area will be cleared of vegetation, debris, pavement, and concrete down to the level of the overburden. The Overburden Soil in the area being excavated will then be removed. Because of the very weak nature of the Organic Residue, several feet of the Overburden Soil will be retained where the excavation equipment and trucks are working. Excavation will begin in the northeastern portion of the Site adjacent to Building 6. The excavation will move south to the southeast corner of the Site near the corner of Bataan Avenue and Australia Street. The excavation area will then move northwest from this point. Overburden material will be carefully excavated to separate Overburden from the Organic Residue. The contractor will segregate Overburden material from Organic Residue to the extent feasible, to avoid co-mingling these two materials. A small amount of Overburden may be excavated and treated with the Organic Residue.

The Overburden Soil will be excavated and placed in 10-wheel trucks and transported to the northeastern corner of the Site for stockpiling in 200 cubic yard piles. These piles may be consolidated if test results confirm their suitability for reuse at the site (see Figure 2). The Organic Residue will then be excavated, placed in 10-wheel trucks, and transported to the treatment pad. Stained and Oily Soil that is encountered as Overburden Soil will be excavated and taken to a separate stockpile area where the soil will be placed on 10-mil plastic sheeting and covered with visqueen Stockpiles of Stained and Oily Soil will be bermed to contain any precipitation runoff and covered with 10-mil black plastic sheeting at any time except when actively worked on pile to reduce odor emissions. After removal of these materials, it is expected that native clayey and sandy materials will be exposed in the bottom of the excavation. Lateral excavation will continue to the limits of the base case as shown in the Construction Drawings (EKI, 2005) and on Figure 2. The Client Representative may direct the Contractor to modify the limits of the Base Case Excavation, as necessary, in accordance with the Project Specifications.

Stained and Oily Soil found adjacent to the Organic Residue will be excavated, transported, and stockpiled in 200 cubic yard stockpiles at a designated area on the Site as shown on Figure 2. The soil will then be tested and characterized following protocols set forth in the SAP (Appendix B, Draft RDIP; EKI, 2004). The analyses may indicate that the Stained and Oily Soil stockpile will not require off-site disposal and may be acceptable for reuse on site.

All soil can be reused as backfill material if it meets Remediation Goals as specified in the RAP (EKI, 2002a) and is not a Federal or State of California Hazardous Waste as stated in *Soil Reuse, Former Oakland Army Base—EDC Area, Oakland, California* (DTSC, 2004). Testing procedures for verifying that soil is not a hazardous waste are described in the SAP (Appendix B, Draft RDIP; EKI, 2004).

Additional sampling and analysis of the Stained and Oily Soil stockpile will be required in accordance with the soil reuse requirements for confirmation of Overburden Soil for reuse as backfill material at the Site. In addition to the chemical remediation goals, the Stained and Oily Soil must also be found suitable for reuse as backfill in accordance with the geotechnical requirements provided in the Contract Documents (EKI, 2005) prior to its use as backfill for the excavation.

If analytical results of the representative sample from a stockpile of Stained and Oily Soil indicates that the material is not acceptable for reuse on-site and is found to be non-RCRA hazardous waste, the stockpiled material will be characterized for off-Site disposal and loaded, transported, and disposed at an appropriately permitted non-RCRA hazardous waste disposal facility.

2.6 Treatment Pad Stockpiling

It is anticipated that the initial separation of potential Building 1 Remediation Waste from Overburden, Stained and Oily Soil and native clayey and sandy sediments can be performed based on the color and consistency of the Organic Residue. Based on observations made during previous investigation including the *Treatability Test Field Activities Report* (EKI 2003) the Organic Residue appears as a spongy, black and tarry material.

It is anticipated that the Organic Residue stockpiles will be heterogeneous in nature and could include small quantities of Overburden or underlying clayey and sandy sediments.

The effectiveness of this separation will be tested during the first 1,000 cubic yards of excavation to verify the proposed procedures.

The initial excavation will begin in an area shown to contain potential Building 1 Remediation Waste. After removal of the Overburden Soils, the first five 200 cubic yard stockpiles of materials thought to be potential Building 1 Remediation Waste will be placed on the treatment pad in 200 cubic yard stockpiles. The stockpiles will be kept separate throughout the sampling and treatment process. A space of approximately 12 feet will be maintained between adjacent stockpiles. The stockpiles will be covered with plastic sheeting to minimize potential odors until the Contractor is ready to treat the stockpile.

2.7 Batch Tracking

Each stockpile/treatment batch will be tracked separately to verify that the batch is correctly processed and to optimize flexibility of the remediation process. Tracking will be accomplished through the use of marked field stakes, a tracking form (see Appendix B), and a daily updated plan sheet. Wood laths (a minimum length of 3 feet) will be staked on each physical batch stockpile. The Batch Number (BN) of the Treatment Batch Tracking Form (Appendix B) will be marked on the wood stake with a permanent ink pen. The stake will identify the batch and tie the stockpile to the corresponding batch tracking paperwork. The sampling coordinator will prepare and maintain the wood stakes and update the batch forms to ensure that each soil pile will be definitively linked to its tracking form. The sampling coordinator will also maintain a plan sheet showing the identification and location of each batch currently being processed. This plan will be updated daily to provide redundancy in case a stake is lost. The management of the stockpiles and the duties of field personnel responsible for the batch tracking is described in detail in the SMP (Northgate, 2005h).

The Treatment Batch Tracking Form (Appendix A) will document the following items:

1. Stockpile/treatment batch number;
2. The date of excavation;
3. The source location by grid quadrant and depth of each discrete soil sample;
4. Sample identification numbers using a naming convention indicating whether untreated or treated;
5. Analytical testing performed on untreated samples;
6. Date of treatment;
7. Reagent application rate;
8. Pre-treatment and post-treatment test results;
9. Documentation that ATS was attained for each treatment batch;
10. The date of each treatment batch volume that was re-treated, if necessary;
11. Name, date, and analytical laboratory results of each re-treated treatment batch;
12. The date the treatment batch was loaded, transported, and disposed; and
13. Certification by the Contractor.

The Treatment Batch Tracking Form will be keyed to the manifests for tracking purposes.

2.8 Testing and Characterization

As previously noted, the Organic Residue has been observed to have an acidic pH and soluble lead concentrations above 5.0 mg/L. Given the correlation between these two parameters, pH will be used as the primary screening criteria for the need to treat the stockpiled Organic Residue. This relationship will be confirmed by testing the first five 200-cubic yard stockpiles of Organic Residue for pH and lead by the TCLP procedure. If these initial results confirm that Building 1 Remediation Waste can be identified based on physical characteristics observed during excavation and pH measurements, then pre-treatment samples will be collected from subsequent stockpiles of Building 1 Remediation Waste. These samples will be archived and tested for soluble lead only if post-treatment TCLP analyses exceed 5 mg/L. (Note: the maximum holding time for samples for TCLP testing is 6 months.) However, if tests for the first five 200-cubic yard stockpiles do not confirm the correlation between acidic pH and soluble lead concentrations, then pre-treatment TCLP testing will continue to be used until observation of field characteristics and pH measurements are demonstrated to reliably characterize Building 1 Remediation Waste.

The procedure for collecting representative samples from each of the stockpiles is described below.

The Organic Residue stockpiles will be spread into separate treatment areas on the treatment pad in an 18-inch lift. Four discrete sub-samples will be collected per treatment batch in accordance with the SAP in Appendix B of the Draft RDIP (EKI, 2004).

The four discrete sub-sampling locations will be selected randomly within the four quadrants to account for the potentially heterogeneous nature of the stockpiles. This approach is based on ASTM Standard D6009-96 (*Standard Guide for Sampling Waste Piles*), which recommends performing general random sampling when a waste pile is considered to be randomly heterogeneous. Once the stockpile has been spread, it will have an approximate surface area of 3,600 square feet, making each quadrant approximately 900 square feet. Each quadrant will be divided into 5- by 5-foot squares and assigned a sequential number from 1 to 36. A number between 1 and 36 will then be randomly generated using a calculator or a computer, or picked from a random number table.

The discrete sample will then be collected from the center of the corresponding square. This random sampling approach is in compliance with the U.S. EPA's *RCRA Waste Sampling Draft Technical Guidance* (EPA530-D-02-002). In the judgment of OBRA's or DTSC's field representatives, biased samples may be collected from the excavated Organic Residue material (in lieu of the above random sampling procedure) if OBRA's or DTSC's field representative determines that the material is not randomly heterogeneous.

The four discrete sub-samples will be composited into one sample for field pH measurements and laboratory analysis, as described further below.

Field screening for pH will be performed to verify the acidic nature of the Organic Residue.

Field screening of soil/waste pH will be performed in accordance with EPA Method 9045D (Soil and Waste pH) , with the exception of minor modifications to account for practical application of the method outside of a formal laboratory setting. The modified method will be performed as follows:

1. The pH meter used will be calibrated at a minimum of two points that are approximately three pH units or more apart. Calibration readings must be within 0.1 pH units of the buffer solution value. The pH meter used will include means for temperature compensation, a glass electrode, and a constant potential reference electrode.
2. Approximately 20 grams of soil/waste sample at its natural moisture content will be measured into a 50-millilter (mL) beaker.
3. Approximately 20 mL of the composite deionized water will be measured into the 50-mL beaker.
4. The beaker will then be covered and continuously stirred/mixed for 5 minutes.
5. The suspension will be allowed to stand for a minimum of 1 hour.
6. The pH will be measured in the aqueous phase and recorded.

If the sample temperature differs by more than 2ºC from the buffer solutions, the measured pH value will be corrected. If the soil/waste absorbs all of the deionized water, an additional 20 mL of deionized water will be added to the beaker before continuing to step 4. The pH of the four-point composite sample will be measured to determine the pH of the stockpile.

The pH field screening results for the first five composite soil/waste samples will be confirmed by laboratory analysis of pH using the same EPA Method (9045D). Provided that the laboratory analytical results per stockpile are within 1.0 pH units of the field screening results per stockpile, laboratory confirmation of field pH screening results will be discontinued. Otherwise, laboratory confirmation of field pH screening results will continue until adjustments to the field screening method produces results which meet the above criteria. During the above process, the required time to obtain a reliable field pH measurement will also be checked.

2.9 Debris Removal

Following pre-treatment sampling, the treatment batch will be pre-treated to remove debris, if present, and separate and crush material larger than 4 inches in any dimension, such as lumps and rocks which can interfere with mixing of chemical reagents. Any material larger than 4 inches will be handpicked and hand cleaned of loose materials during spreading of each 200 cubic yards batch. Manually collected debris such as rock, roots, brick, and tires will be will be stockpiled on plastic sheeting. Concrete debris will be crushed prior to stockpiling. Stockpiled material will be managed as debris following protocol as described in Section 8 of the SAP (Appendix B, Draft RDIP; EKI, 2004) for additional disposal sampling. Following profiling according to analytical test results, the material will be re-used on site or disposed at an approved landfill. Vegetation material and construction debris will be disposed at Keller Canyon landfill. If a sufficient quantity of steel is recovered, it will be recycled at Schnitzer Steel in Oakland. Recyclable concrete will be transported to either Specialty Crushing, Syar-Richmond, or Inner-City Demolition in Oakland (market dependant). For on-site reuse, test results will be compared to remediation goals for COCs, as shown in Table 7-11 of the RAP (EKI, 2002a) and hazardous waste identification criteria pursuant to the California Code of Regulations, Title 22, Division 4.5, Chapter 11. Depending on the analytical results, materials will be recycled or disposed at an approved landfill

2.10 Mixing

Reagent will be applied by spreading the reagent on the surface of the 18-inch thick lift of Building 1 Remediation Waste using a spreader. Approximately 13.6 tons of reagent will be necessary to treat a 200-cubic yard treatment batch. It is Pacific States' intent to have the reagent delivered to the Site at the time of mixing. No reagent will be stored on-site; all on-site reagent will be used by the end of the day. One representative sample from the reagent will be collected and analyzed for soluble lead (EPA Methods 6020 and 1311), TPHg and TPHd (EPA Method 8015, with silica gel cleanup), Title 22 Metals (Method 6020) and PAH (EPA Method 8310). Existing laboratory analytical data provided by the regent supplier may be provided to OBRA instead of performing additional laboratory analyses.

The selected treatment reagent will be Permanente Type II portland cement (see Appendix C, MSDS for portland cement). The supplier is Hanson Permanent Cement, Inc. (Hanson). Here is Hanson's contact information:

Hanson Permanente Cement, Inc.
Carole E. Culbreath, Customer Services
3000 Busch Road
P.O. Box 309
Pleasanton, California 94566-0030
Telephone: (925) 846-8800

KEMRON Environmental Services, Inc.(KEMRON) tested Type I Portland Cement during the previous treatability study performed at the Site for OBRA. Results of the Study are presented in the Treatability Test Filed Activities Report, Erler and Kalinowski, Inc., 2003. Although Type I was previously tested and confirmed to effectively stabilize the Organic Residue, the use of Type II portland cement is expected to perform comparably to Type I portland cement (personal communication between Mark Clark, KEMRON, , and Keith Wayne, Pacific States on August 22, 2005).

The planned dosage rate of proposed treatment reagent is 5 percent (by weight). The dose may be re-evaluated based on post-treatment test results.

No other additives are proposed to attain the ATS and other required landfill acceptance criteria for the designated permitted disposal facility

The treatment will be implemented by mixing the treatment reagent and the batch material with a soil grinder to a depth of 18 inches to combine the reagents and Building 1 Remediation Waste.

The treatment is intended to stabilize high concentrations of lead that are found in the Organic Residue, raise the pH of the material, and reduce the moisture content. The methodology for treatment is presented on Figure 5.

Curing is equal to the duration of mixing by the immediate reaction at the initial hydration that controls the pH level. Since strength gains are not a requirement for the project, additional cure time would not be necessary after the initial hydration of the soil-cement.

2.11 Re-Stockpiling, Waste Profiling, and Disposal

The treated batch will be left in place in an 18-inch lift at the mixing area as shown on Figure 4 until post treatment sampling for the batch is accomplished. Four discrete sub-samples will be collected per treatment batch in accordance with the SAP in Appendix B of the Draft RDIP (EKI, 2004).

The four discrete sub-sampling locations will be selected randomly within the four quadrants to account for the potentially heterogeneous nature of the stockpiles. This approach is based on ASTM Standard D6009-96 (*Standard Guide for Sampling Waste Piles*), which recommends performing general random sampling when a waste pile is considered to be randomly heterogeneous.

The spread batch has an approximate surface area of 3,600 square feet, making each quadrant approximately 900 square feet. Each quadrant will be divided into 5- by 5-foot squares and assigned a sequential number from 1 to 36. A number between 1 and 36 will then be randomly generated using a calculator or a computer, or picked from a random number table.

The discrete sample will then be collected from the center of the corresponding square. This random sampling approach is in compliance with the U.S. EPA's *RCRA Waste Sampling Draft Technical Guidance* (EPA530-D-02-002).

The four discrete sub-samples (8 ounces per sub-sample) will be composited in the field by combining them in a pre-cleaned stainless-steel bowl, and thoroughly mixing the treated material using pre-cleaned, stainless-steel hand tools to form a homogeneous sample. After mixing, the soil will be divided into two halves, and placed into new, laboratory-supplied glass jars for chemical analyses (original and duplicate, to be held for possible additional testing). The composite samples will be sent under Chain of Custody protocol to a laboratory to be tested for the following:

- Lead by EPA Method 6020 in TCLP extract using TCLP Method 1311 provided in SW-846;
- pH by EPA Method 9045;
- Moisture content by ASTM Method D2216.

If the analytical tests show that the soluble lead concentration is below 5 mg/L, pH is greater than 4, and percent moisture is less than 50 percent by weight, the material will then be hauled off-site and disposed as a non-RCRA hazardous waste. If analytical test results for TCLP exceed 5 mg/L, the pretreatment sample will then be placed on hold and the batch tested to assess if the ATS reduction of leachable lead has been achieved. If the 77 percent reduction has been achieved and the other testing requirements are met, the material will be removed from the Site and disposed as a RCRA hazardous waste subject to ATS variance. Whenever the post-treatment sample's lead TCLP result exceeds 5 mg/L, Pacific States will analyze the archived pre-treatment sample to verify ATS achievement. The methodology for waste profiling and disposal is presented on Figure 6.

Materials that may be disposed of as hazardous waste, including Building 1 Remediation Waste and Oily and Stained Soil, will be characterized in accordance with the requirements of the disposal facility (CWM Kettleman Hills Landfill, of Kettleman City, California). In addition to providing the facility with relevant historical analytical data, additional data for pH, lead, moisture content, or other analyses required by the landfill will be submitted. The pH of treated Building 1 Remediation Waste must be between the values of 4.0 and 12.5.

During off-haul, trucks will enter onto the treatment pad, be loaded, tarped, will exit the treatment pad through the decontamination area, and be inspected prior to departing the Site.

Detailed traffic control measurements and decontamination procedures are described in the DP (Northgate, 2005a) and the TCTP (Northgate, 2005i).

3.0 QUALITY ASSURANCE

QA measures for the soil treatment process will be conducted in compliance with the RAP (EKI, 2002a), RMP (EKI, 2002b), Site-Wide Quality Assurance Project Plan (Veridian Environmental, 2005) and the Draft RDIP (EKI, 2004). Compliance with these documents will ensure that analytical data produced during the soil treatment process will be of known and sufficient quality to allow for appropriate and effective management of classified soil. The established QA procedures have been specifically designed to facilitate the quick decision process necessary to conduct cost-effective remediation activities. Aspects of the soil treatment process that will be governed by established QA procedures include project management, data generation and acquisition, assessment and oversight, data validation, and usability.

3.1 Project Management

The Contractor and subcontractors will assign key field personal to be responsible for the implementation of the QA measurements and to assure compliance with the applicable Site QA documents.

3.2 Soil Treatment QA Measures

This QA measure identifies engineering controls for soil stabilization with portland cement, including inspection and testing requirements.

The quality of stabilized mixtures, as produced, must be monitored on a continuing basis to ensure a quality product. The tests to be conducted on these materials are listed below:

1. In-place density and moisture content (ASTM 2922); and
2. Stabilizer content (ASTM D2901-99, *Standard Test Method for Cement Content of Freshly Mixed Soil-Cemen*t).

3.3 Reagent Spreading and Dose Control

A front loader will spread the stockpiled Building 1 Remediation Waste in a manner that will avoid foot traffic and equipment wheel loading that could lead to variations of the density of the 18-inch layer. Prior to placement of reagent, field personal shall determine the depth of the treatment layer and average in-place moisture content and dry soil density using a nuclear gauge. This will be used to determine the weight of reagent to apply per square foot to the Building 1 Remediation Waste. The reagent application rate will be based on the in-situ soil's dry density in pounds per cubic foot.

When cement is applied to soil, the spread rate shall be determined by placing a 3 square foot pan on the ground in front of spreader. After the cement has been spread, the reagent will be weighed in the pan to determine the rate of spread in pounds per square foot. The spreader is equipped with a computer controlled metering device for accurate spread rates. Reagent shall be spread uniformly distributing the required amount of cement for the full depth and width of the treatment batch. All cement spread shall be thoroughly mixed into the soil the same day cement spreading operations are performed.

No traffic other than the mixing equipment will be allowed to pass over the spread cement until the mixing process is completed.

3.4 Mixing QA Measures

Mixing equipment shall be equipped with a visible depth indicator showing mixing depth, and an odometer or foot meter to indicate travel speed.

Mixing and re-mixing shall continue until the material is uniformly mixed, free of streaks or pockets of cement, and the moisture content is less than 50 percent by weight.

High-speed mixing equipment does not use blades, but rather bullets teeth. If material is encountered that gums up a rotor, it would be treated as a maintenance issue. A representative of Griffin Soil of Pleasanton, California, would be required to visually inspect this type of material to determine if other measures would be required during the mixing operations.

3.5 Reagent Handling

Field personnel will assure that the cement used in the treatment process has not been rendered non-reactive through improper handling. The reagent supplier shall provide specifications for hydrated cement and information on handling requirements. At a minimum, the portland cement shall be protected from moisture until used, and shall be sufficiently dry to flow freely when handled.

3.6 Surface Soil

Surface soil samples will be collected at evenly distributed locations around the treatment pad following preparation of the pad site and after treatment pad removal. Additional pre- and post-construction surface soil samples will be collected at the delineated haul road to verify that soil was not impacted by the transportation of materials during remediation. Surface soil samples also will be collected at one location at the decontamination pad following preparation of the pad site and after removal of the decontamination pad. Figure 2 identifies these surface soil sample locations. Samples will be analyzed for the following:

- lead (EPA Method 1311 and 6010B);
- pH (EPA Method 9045C);
- moisture content (Standard Method 2540G); and
- total hydrocarbons (modified EPA Method 8015 with silica gel cleanup).

In addition, additional samples may be collected, if the field observations indicate the presence of liquid staining related to recent treatment activities.

4.0 REFERENCES

California Department of Toxic Substances Control, 2004, Letter entitled *Soil Reuse, Former Oakland Army Base—EDC Area, Oakland, California*

Erler and Kalinowski, Inc., 2002a, *Remedial Action Plan*

Erler and Kalinowski, Inc., 2002b, *Risk Management Plan*

Erler and Kalinowski, Inc., 2003, *Treatability Test Field Activities Report*

Erler and Kalinowski, Inc., 2004, *Draft Remedial Design and Implementation Plan for the Former ORP/Building 1 Area, Former Oakland Army Base-EDC Area*

Erler and Kalinowski, Inc., 2005, *Contract Documents for Former ORP/Building 1 Area Remediation Project*

Northgate Environmental Management, Inc., 2005a, *Decontamination Plan.*

Northgate Environmental Management, Inc., 2005b, *Dust and Odor Control Plan.*

Northgate Environmental Management, Inc., 2005c, *Noise Reduction Plan.*

Northgate Environmental Management, Inc., 2005d, *Perimeter Air Monitoring Plan.*

Northgate Environmental Management, Inc., 2005e, *Site-Specific Health and Safety Plan.*

Northgate Environmental Management, Inc., 2005f, *Soil Treatment Process Plan.*

Northgate Environmental Management, Inc., 2005g, Stockpile Management Plan.

Northgate Environmental Management, Inc., 2005h, *Storm Water Pollution Prevention Plan.*

Northgate Environmental Management, Inc., 2005i, *Traffic Control and Transportation Plan.*

Veridian Environmental, 2005, *Site-wide Quality Assurance Program Plan*

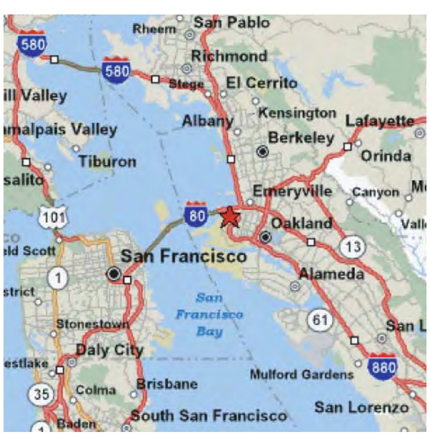
U.S. Environmental Protection Agency, July 1992, *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies*.

U.S. Environmental Protection Agency, 2002, *Site Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Wastes*

U.S. Environmental Protection Agency, 2003, *Amendment 1: Site-Specific Treatment Variance from Land Disposal Restriction Treatment Standards for Hazardous Wastes*

FIGURES

APPROXIMATE LOCATION
NOT TO SCALE



Basemap from Thomas Guide, California, 2004

FIGURE 1
Site Location Map

Former ORP/Building 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

northgate
environmental management, inc.

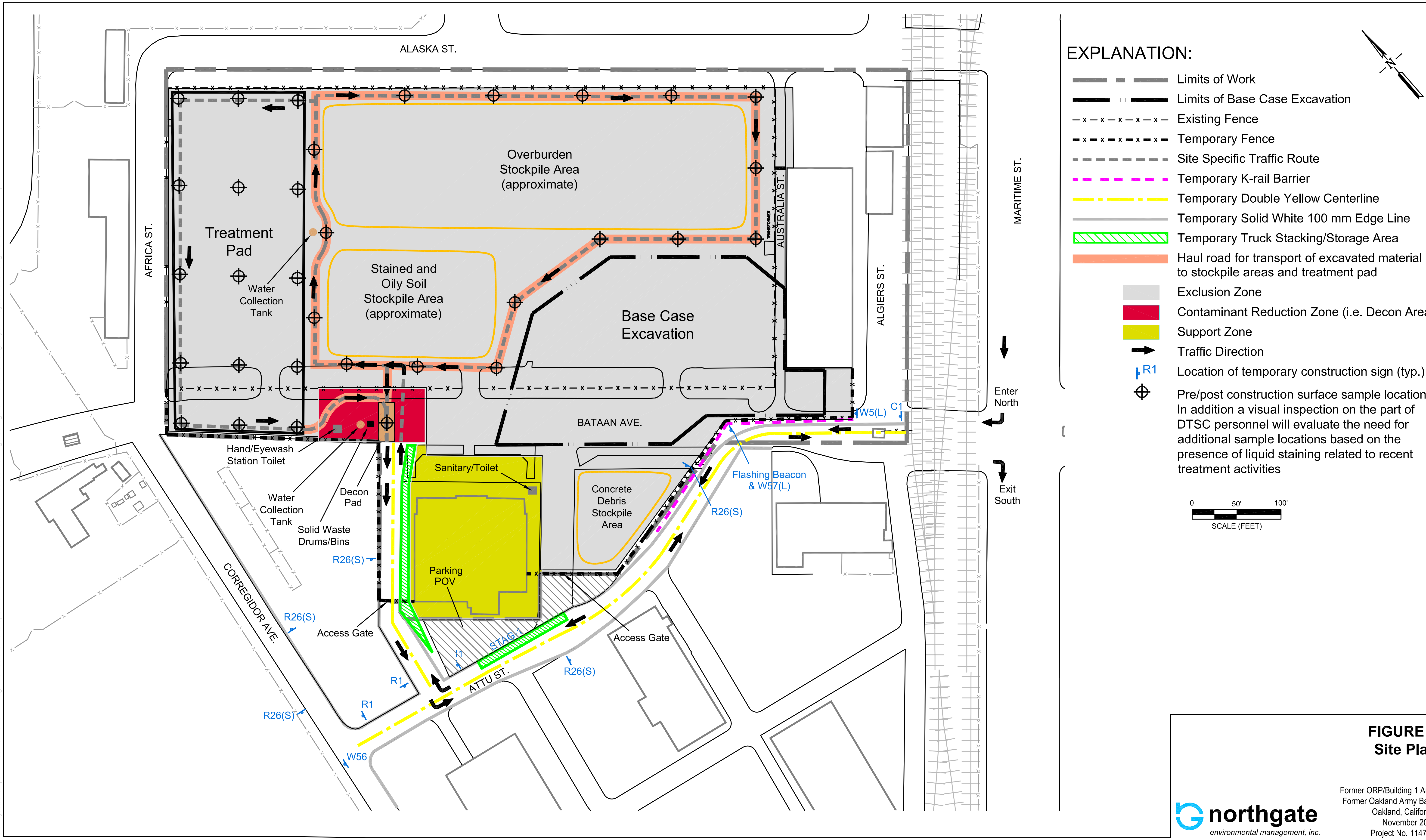
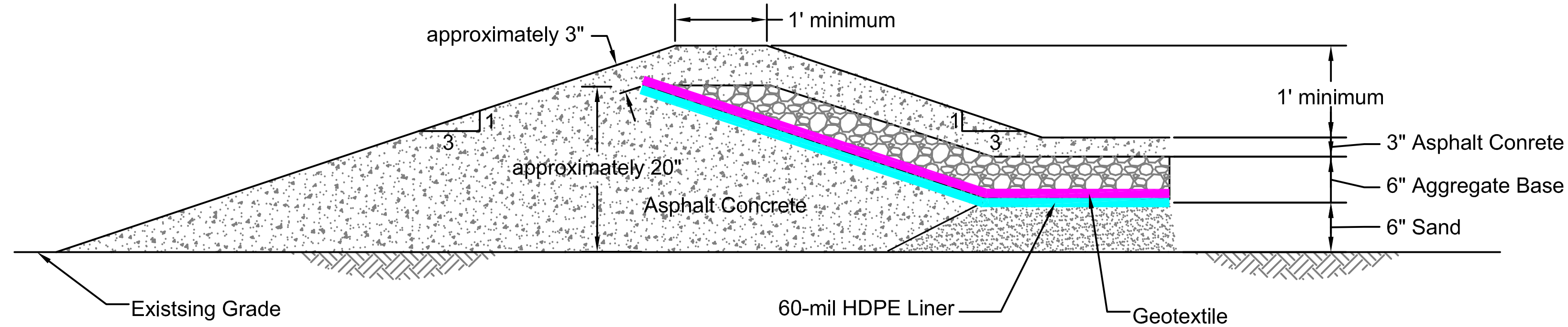


FIGURE 2
Site Plan

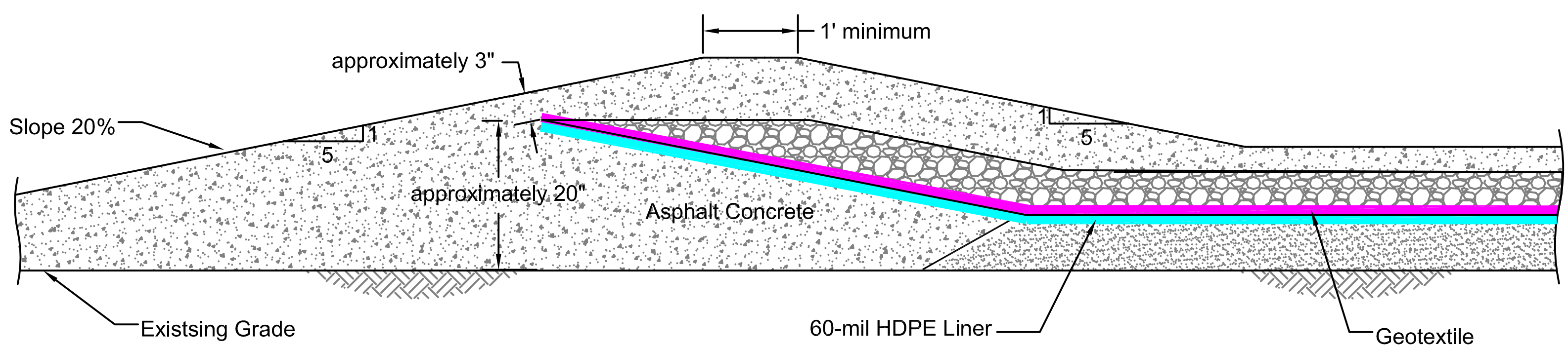
northgate environmental management, inc.

Former ORP/Building 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

Berm at Treatment Pad



Berm at Entrance/Exit



0 2 4

Approximate Scale (Feet)

FIGURE 3
Treatment Pad Section Details

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Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

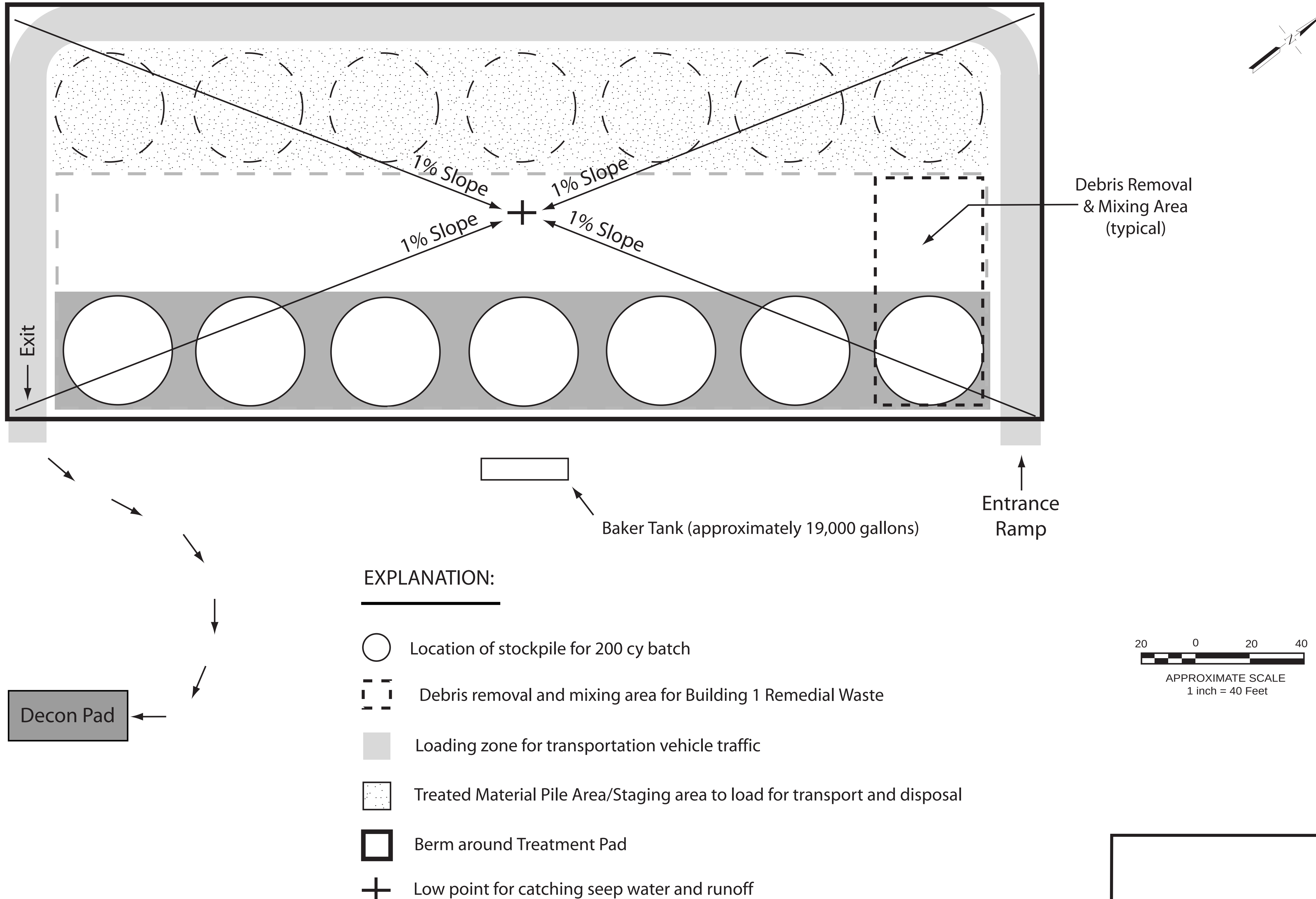

FIGURE 4
Treatment Pad Layout

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Oakland, California
November 2005
Project No. 1147.01

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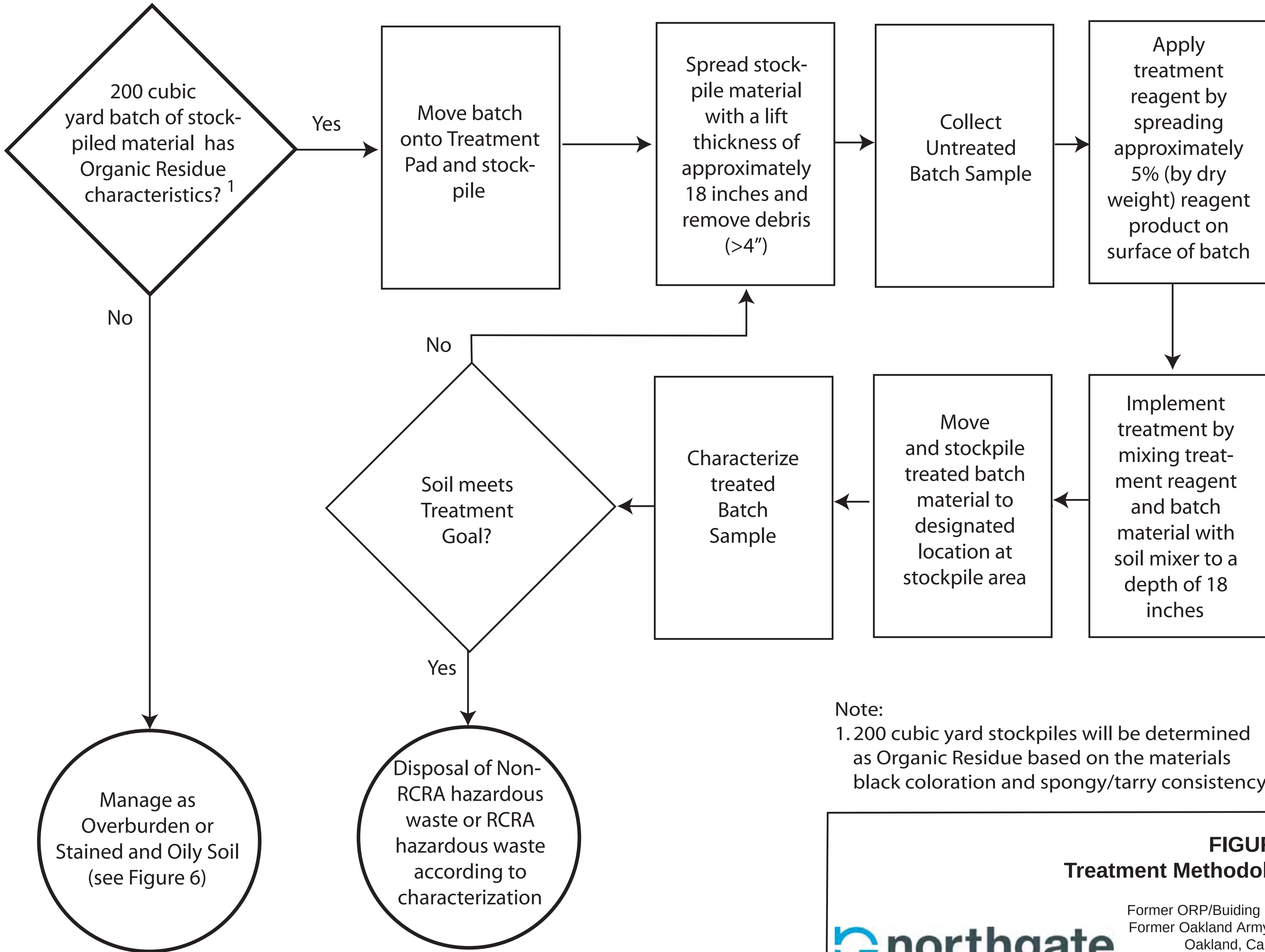

Note:

1. 200 cubic yard stockpiles will be determined as Organic Residue based on the materials black coloration and spongy/tarry consistency.

FIGURE 5
Treatment Methodology

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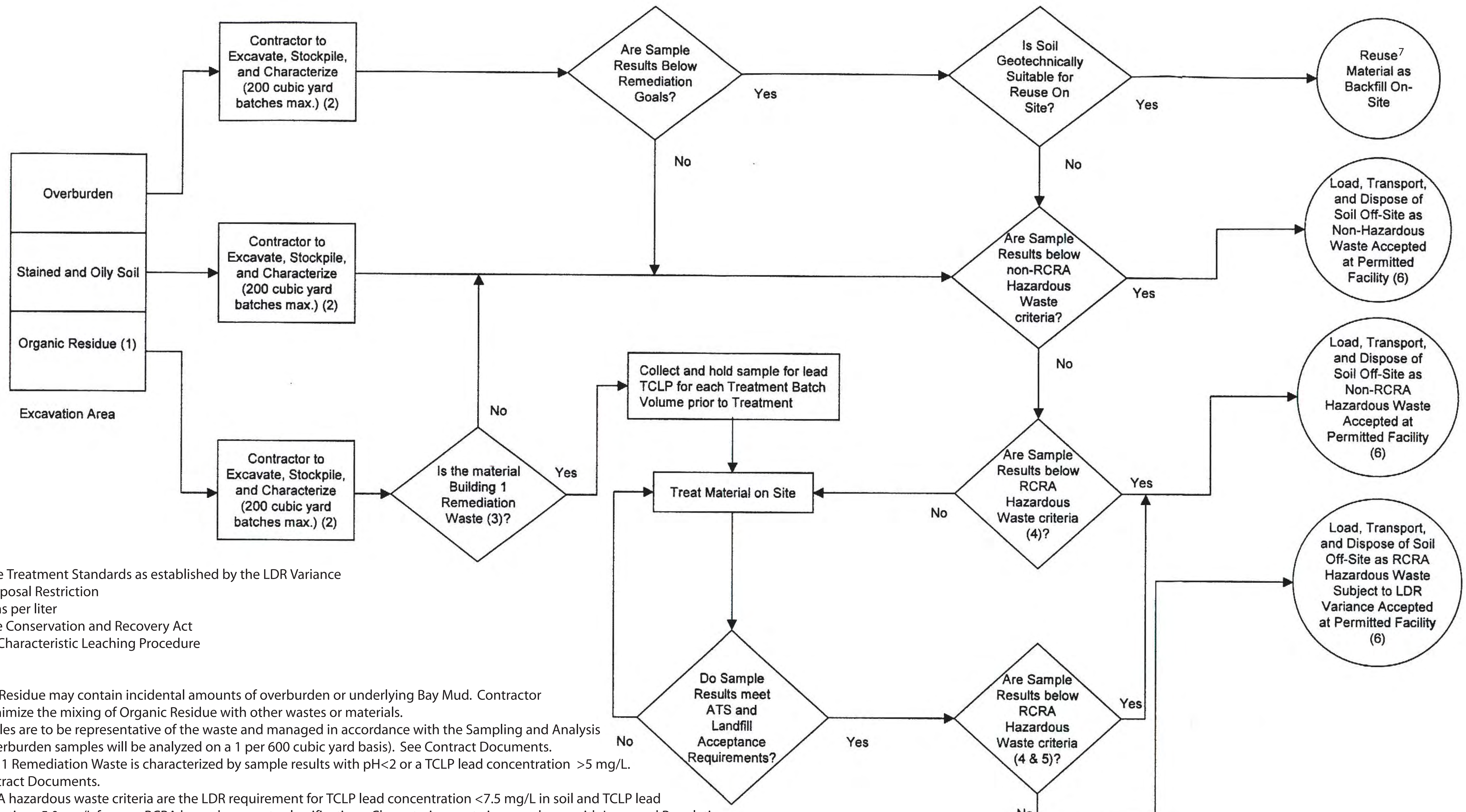
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01



Abbreviations

ATS	Alternate Treatment Standards as established by the LDR Variance
LDR	Land Disposal Restriction
mg/L	miligrams per liter
RCRA	Resource Conservation and Recovery Act
TCLP	Toxicity Characteristic Leaching Procedure

Notes

1. Organic Residue may contain incidental amounts of overburden or underlying Bay Mud. Contractor shall minimize the mixing of Organic Residue with other wastes or materials.
2. All samples are to be representative of the waste and managed in accordance with the Sampling and Analysis Plan (overburden samples will be analyzed on a 1 per 600 cubic yard basis). See Contract Documents.
3. Building 1 Remediation Waste is characterized by sample results with pH<2 or a TCLP lead concentration >5 mg/L. See Contract Documents.
4. Key RCRA hazardous waste criteria are the LDR requirement for TCLP lead concentration <7.5 mg/L in soil and TCLP lead concentration<5.0 mg/L for non-RCRA hazardous waste classification. Characterize waste in accordance with Laws and Regulations.
5. Treated Building 1 Remediation Waste disposed as non-RCRA hazardous waste is subject to the LDR Variance and landfill acceptance criteria. See Contract Documents.
6. All waste classification and coordination with permitted disposal facilities by Contractor shall be in compliance with Laws and Regulations and the Contract Documents. This flow chart is provided as a simplification of the presumed most likely waste management pathways at the Site and is not an exclusive listing of management practices or meant to supercede waste management requirements in Laws and Regulations and landfill acceptance criteria.
7. Base on the review of data, additional testing such as TCLPs and Waste Extraction Test("WETs") may be required to demonstrate that the stockpiled Overburden is not Federal or State of California hazardous waste in accordance with the RAP/RMP requirements for backfill material.

Source: Erler and Kalinowski, Inc., Draft RDIP, 2004

FIGURE 6

Simplified Soil Disposal Classification Flow Chart

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November 2005
Project No. 1147.01

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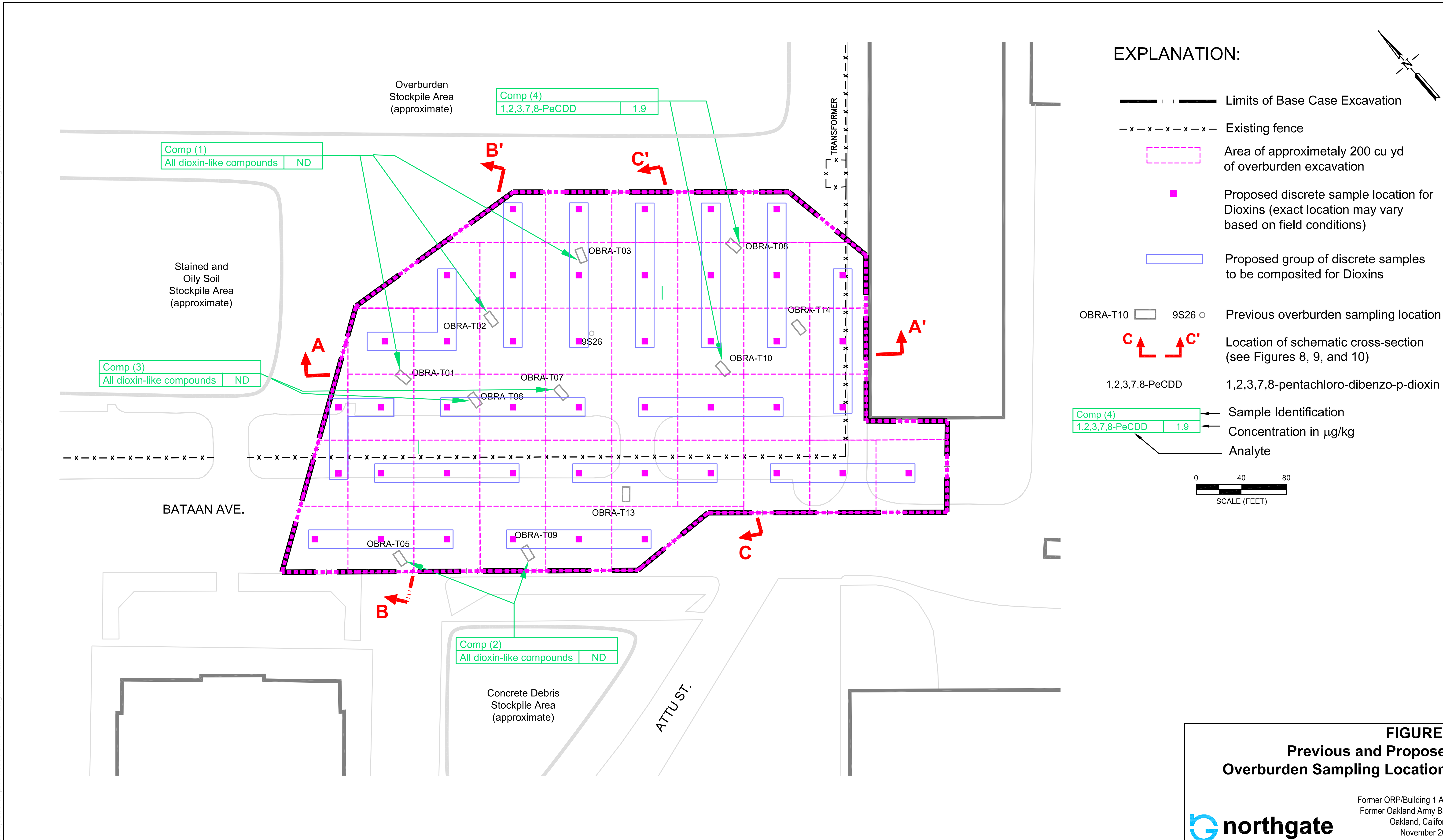

FIGURE 7
Previous and Proposed Overburden Sampling Locations

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Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

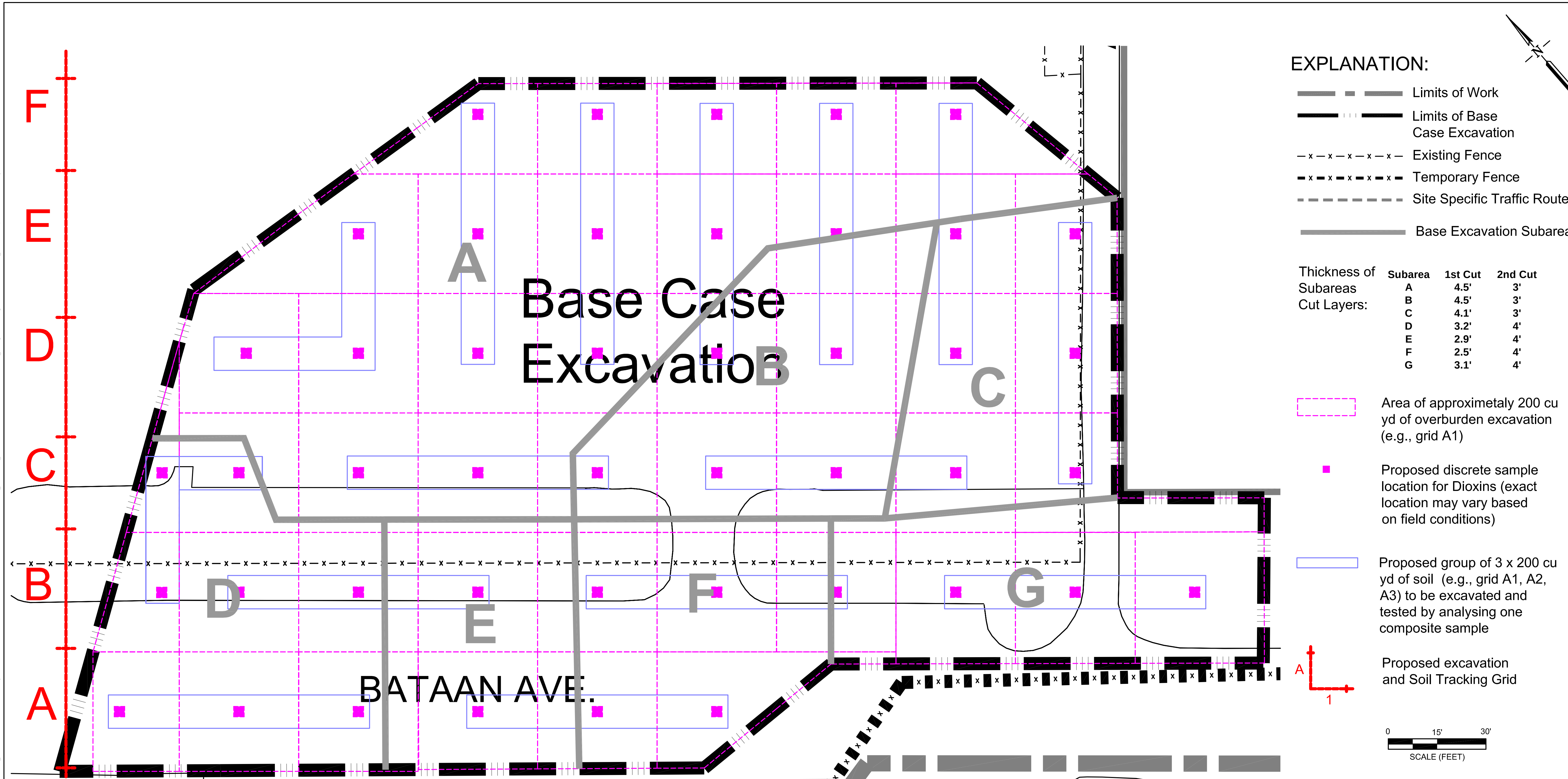

FIGURE 8
Base Excavation Plan

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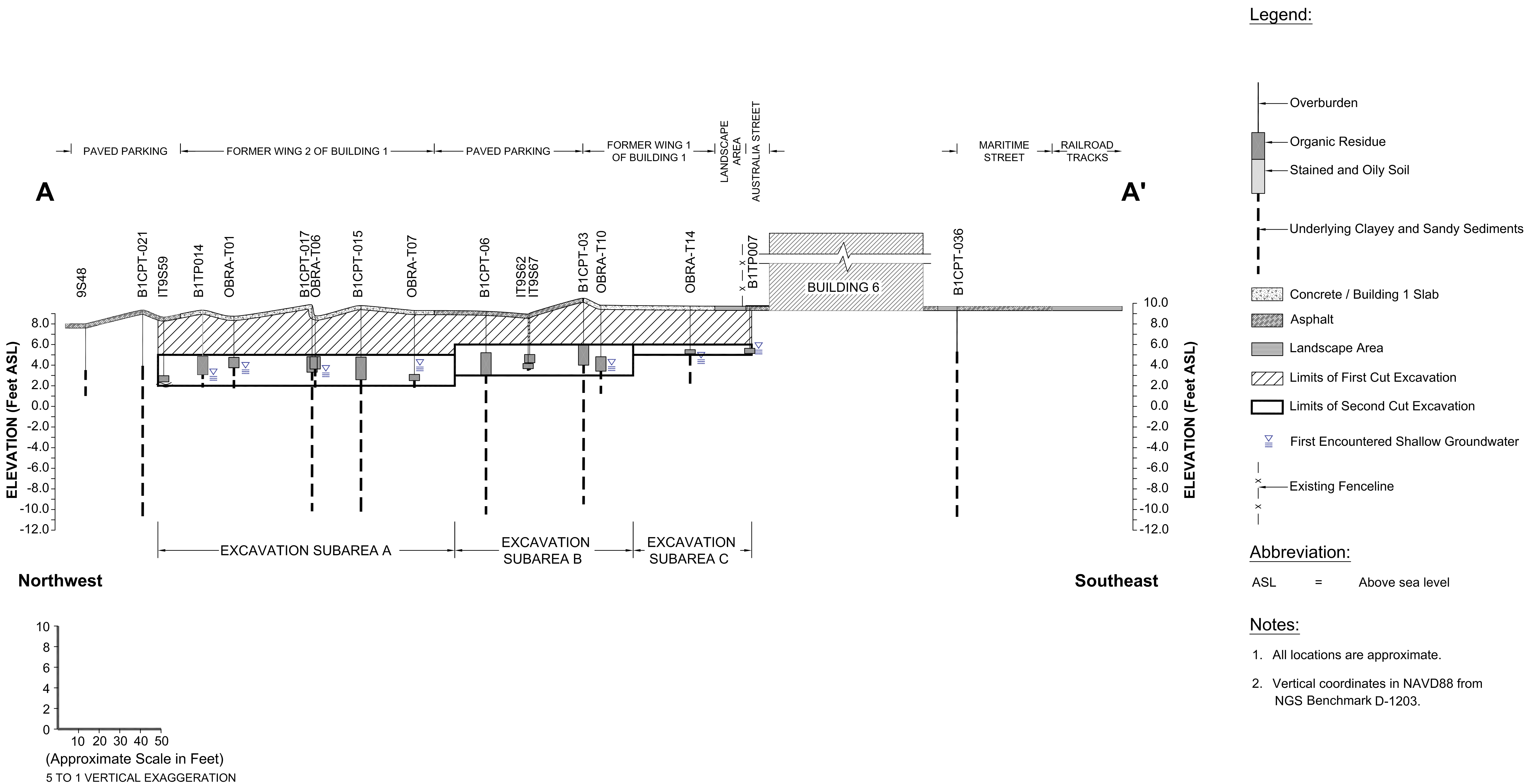
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01



Abbreviation:

ASL = Above sea level

Notes:

1. All locations are approximate.
2. Vertical coordinates in NAVD88 from NGS Benchmark D-1203.

Source: Erler and Kalinowski, Inc., Draft RDIP, 2004

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FIGURE 9

Cross Section A-A'

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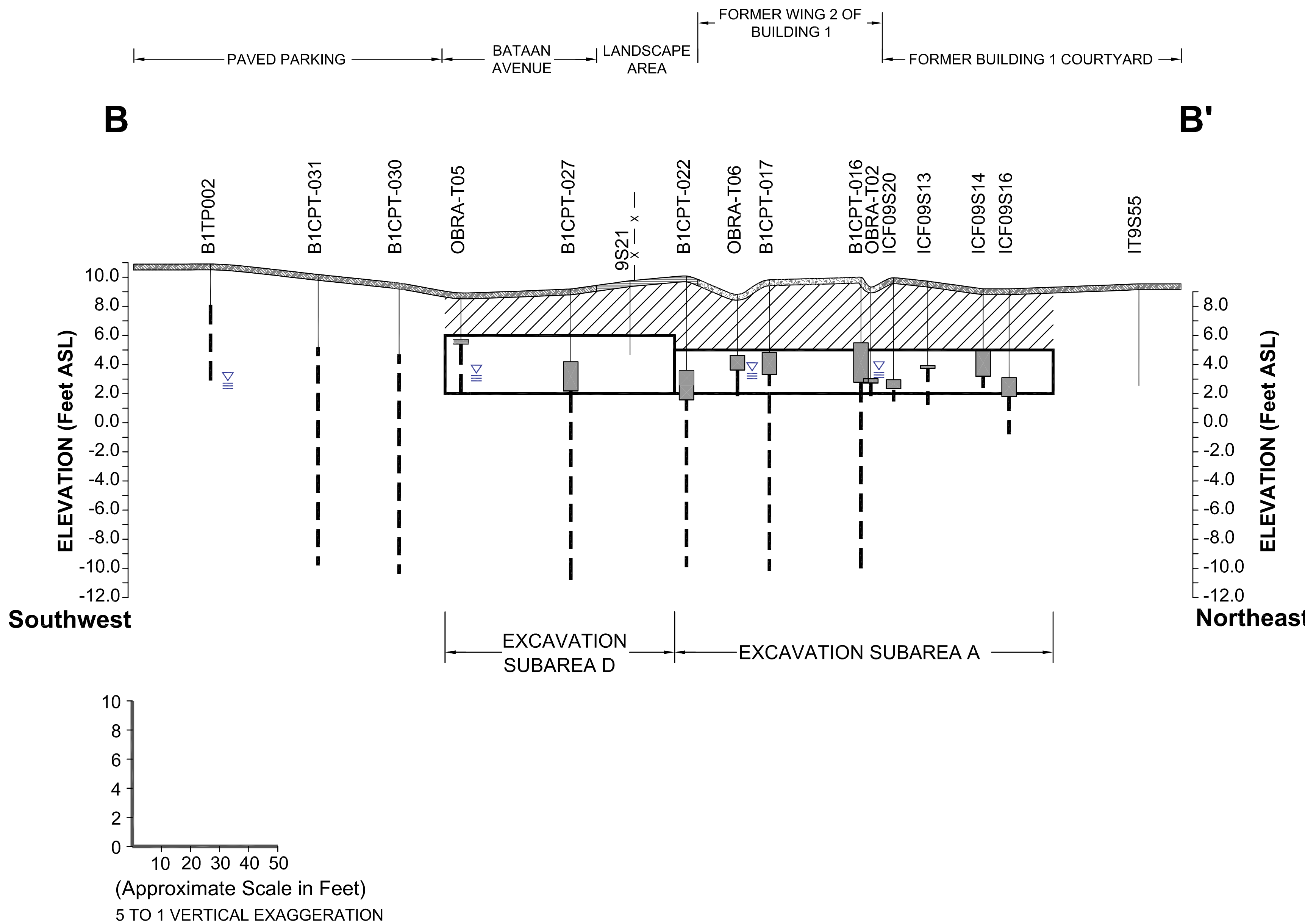
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01



Legend:

- Overburden
- Organic Residue
- Stained and Oily Soil
- Underlying Clayey and Sandy Sediments
- Concrete / Building 1 Slab
- Asphalt
- Landscape Area
- Limits of First Cut Excavation
- Limits of Second Cut Excavation
- First Encountered Shallow Groundwater
- Existing Fenceline

Abbreviation:

ASL = Above sea level

Notes:

1. All locations are approximate.
2. Vertical coordinates in NAVD88 from NGS Benchmark D-1203.

Source: Erler and Kalinowski, Inc., Draft RDIP, 2004

FIGURE 10

Cross Section B-B'

Former ORP/Buiding 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

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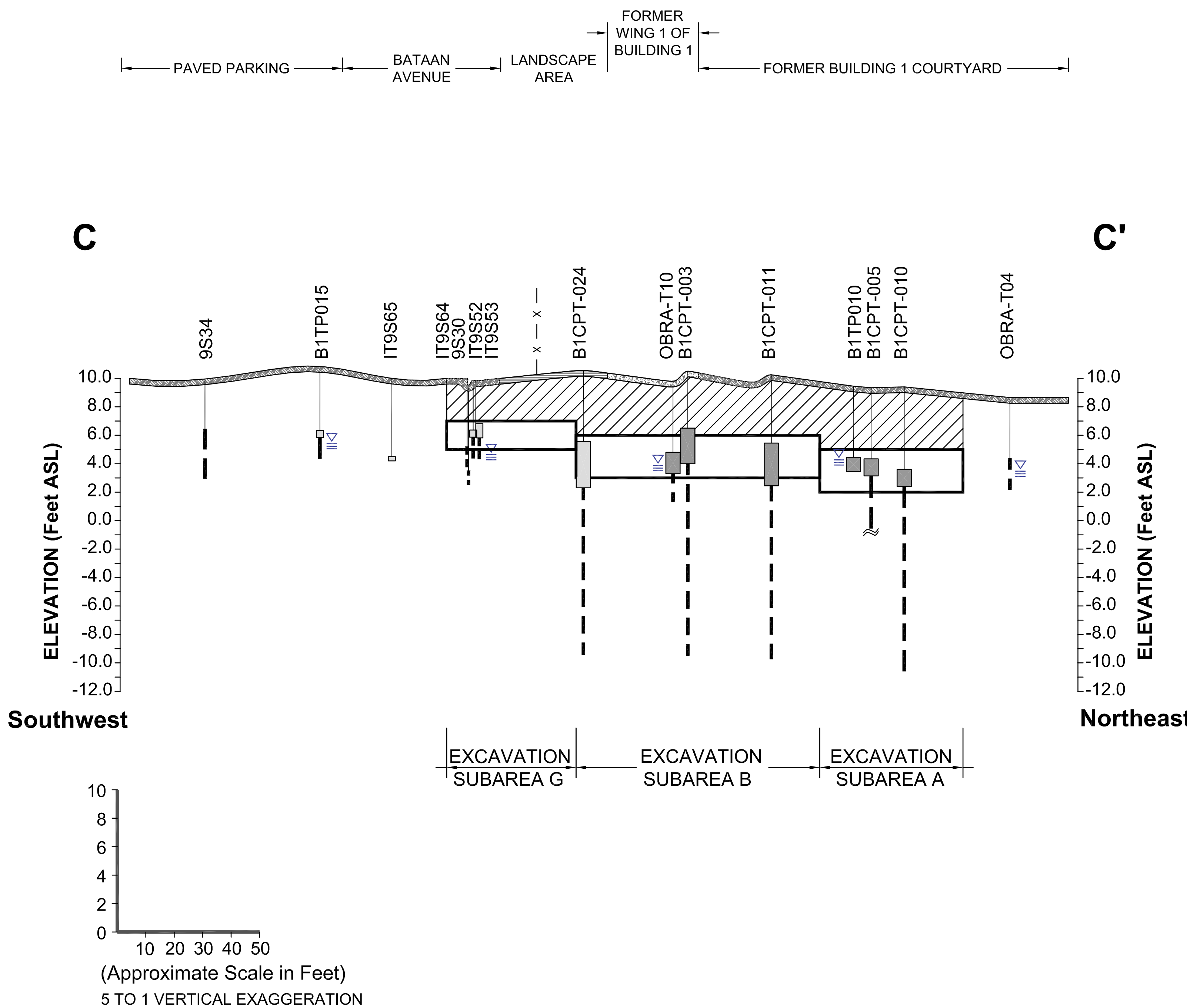

Legend:

- Overburden
- Organic Residue
- Stained and Oily Soil
- Underlying Clayey and Sandy Sediments
- Concrete/Building 1 Slab
- Asphalt
- Landscape Area
- Limits of First Cut Excavation
- Limits of Second Cut Excavation
- First Encountered Shallow Groundwater
- Existing Fenceline

Abbreviation:

ASL = Above sea level

Notes:

1. All locations are approximate.
2. Vertical coordinates in NAVD88 from NGS Benchmark D-1203.

Source: Erler and Kalinowski, Inc., Draft RDIP, 2004

FIGURE 11
Cross Section C-C'
Former ORP/Buiding 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

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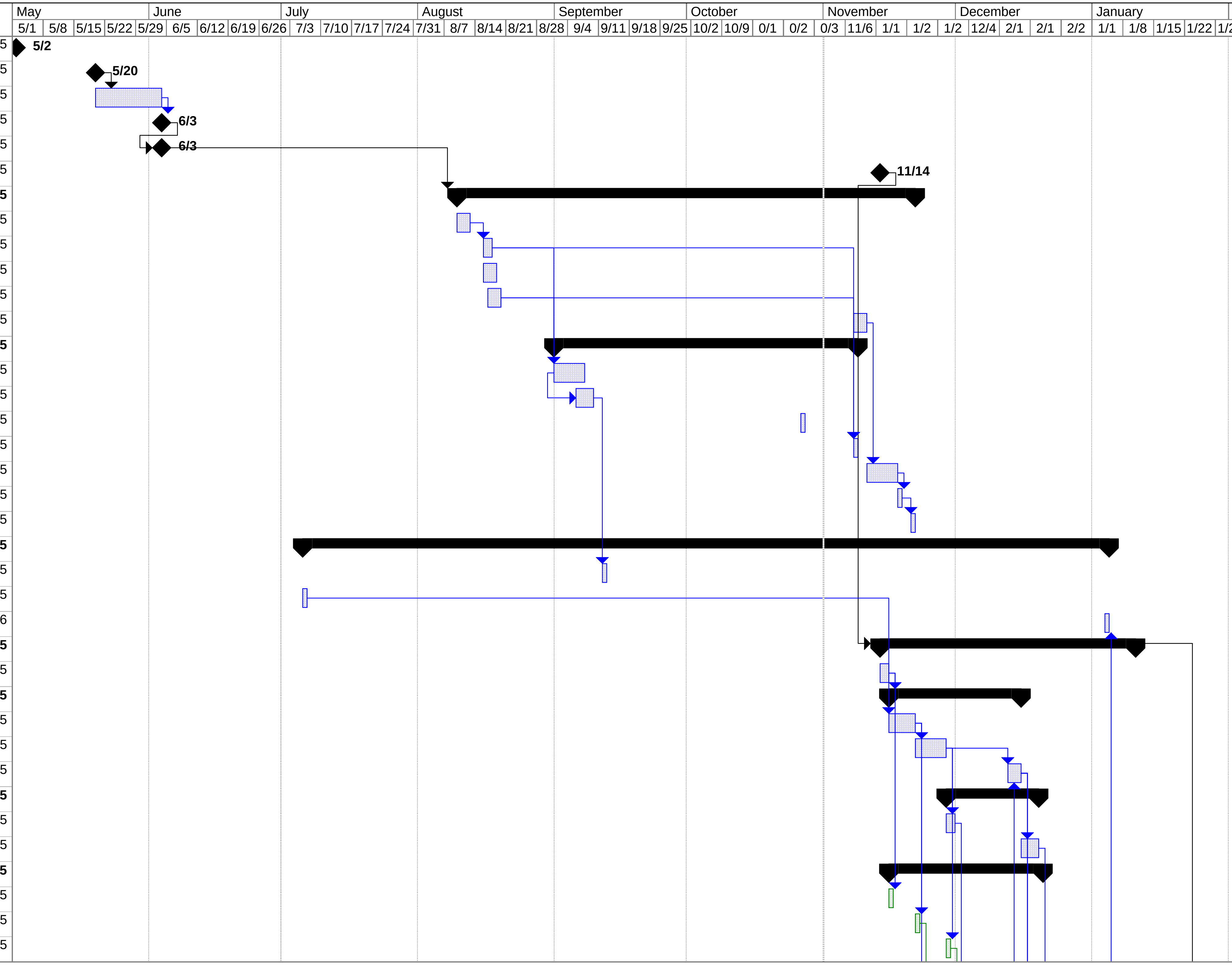
ID		Task Name	Duration	Start
1		Bid Submittal	0 days	Mon 5/2/05
2		Notice of Award	0 days	Fri 5/20/05
3		Negotiate Agreements	2 wks	Fri 5/20/05
4		CTR Signs Contract	0 days	Fri 6/3/05
5		OBRA Issues Preliminary NTP	0 days	Fri 6/3/05
6		Authorization to Proceed	0 days	Mon 11/14/05
7		**Site Preparation & Limited CTR Mobilization**	**73 days**	**Wed 8/10/05**
8		Temporary striping and signage - Chrsip Co.	3 days	Wed 8/10/05
9		Install construction fencing	2 days	Tue 8/16/05
10		Move Equipment into Construction Office	3 days	Tue 8/16/05
11		Install traffic control elements	3 days	Wed 8/17/05
12		Install decontamination pad	3 days	Tue 11/8/05
13		**Preparatory Underground Utility Work**	**48 days**	**Thu 9/1/05**
14		Pothole UG utility locations	4 days	Thu 9/1/05
15		Install temporary plugs, etc	4 days	Tue 9/6/05
16		Hot Tap Gas Lines	1 day	Thu 10/27/05
17		Decommission monitor well MW-37	1 day	Tue 11/8/05
18		Construct treatment pad	5 days	Fri 11/11/05
19		Construct soil stockpile areas	1 day	Fri 11/18/05
20		Set-up work zones	1 day	Mon 11/21/05
21		**Surveying**	**128 days**	**Wed 7/6/05**
22		Survey abandoned/capped utilities	1 day	Mon 9/12/05
23		Mark limits of Base Case excavation	1 day	Wed 7/6/05
24		Final survey of Base Case Excavation	1 day	Wed 1/4/06
25		**Site Remediation**	**40 days**	**Mon 11/14/05**
26		Demolish pavements, fencing, etc.	2 days	Mon 11/14/05
27		**Excavation**	**20 days**	**Wed 11/16/05**
28		Excavation/stockpiling of dry soils, utility removal	4 days	Wed 11/16/05
29		Phase I - Excavation of soft sediments	3 days	Tue 11/22/05
30		Phase II - Excavation of soft sediments	3 days	Tue 12/13/05
31		**Treatment of RCRA wastes**	**15 days**	**Tue 11/29/05**
32		Treat Phase I	2 days	Tue 11/29/05
33		Treat Phase II	2 days	Fri 12/16/05
34		**Soil Sampling & Analysis**	**23 days**	**Wed 11/16/05**
35		Collect overburden samples	1 day	Wed 11/16/05
36		Collect untreated non-reuseable samples	1 day	Tue 11/22/05
37		Collect pre-treatment samples, Phase I	1 day	Tue 11/29/05



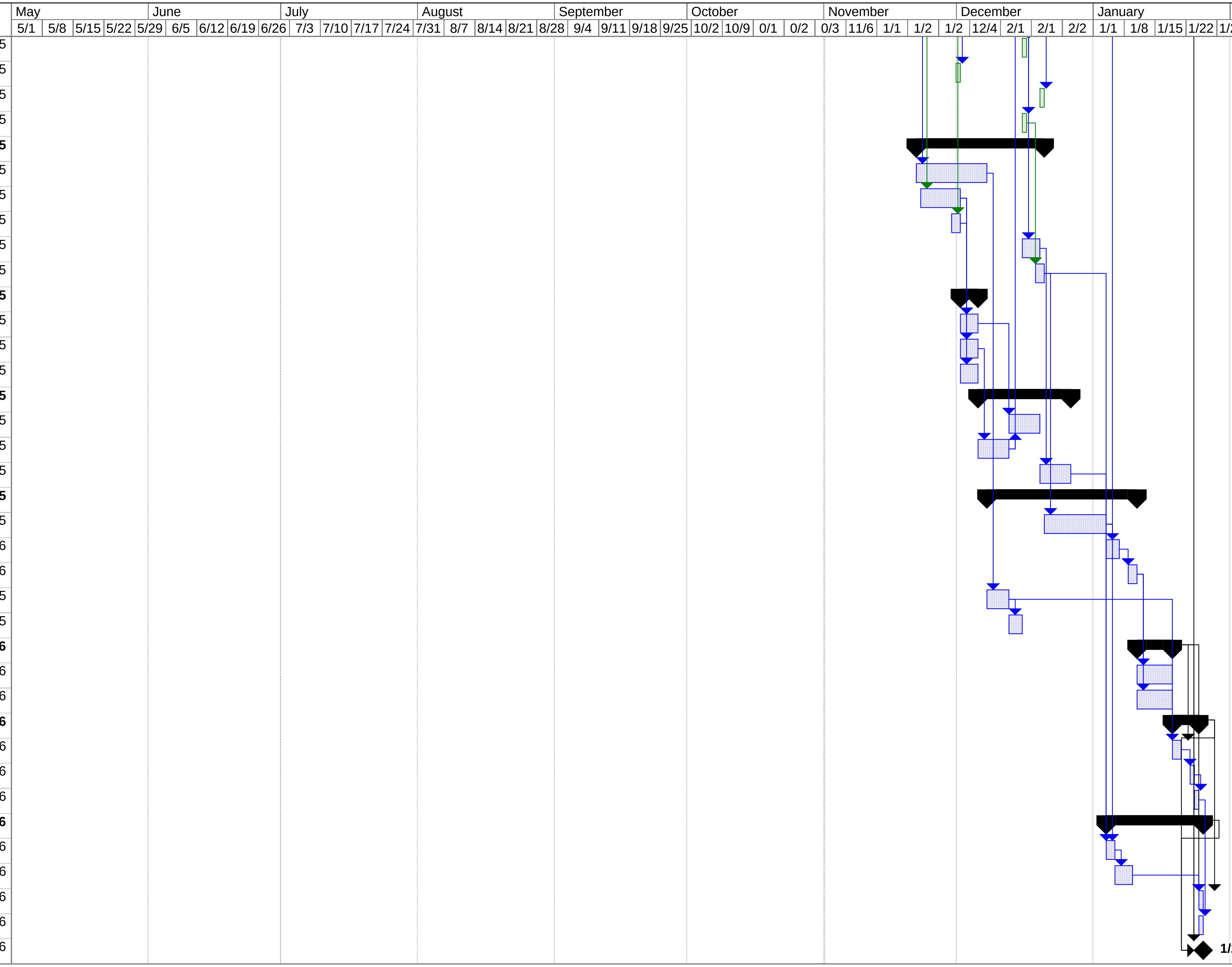
Project: Bldg 1 - ORP Remediation ST
Date: Tue 11/1/05

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

FIGURE 12
Project Schedule

Former ORP/Building 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

ID		Task Name	Duration	Start
38		Collect pre-treatment samples, Phase II	1 day	Fri 12/16/05
39		Collect post-treatment samples, Phase I	1 day	Thu 12/1/05
40		Collect post-treatment samples, Phase II	1 day	Tue 12/20/05
41		Collect excavation confirmation samples	1 day	Fri 12/16/05
42		**Soil Sample Analysis**	**19 days**	**Tue 11/22/05**
43		Overburden analysis	2 wks	Tue 11/22/05
44		Non-reuseable soil analysis	5 days	Wed 11/23/05
45		Phase I pre-treatment analysis	2 days	Wed 11/30/05
46		Phase II pre-treatment analysis	2 days	Fri 12/16/05
47		Confirmation sample analysis	2 days	Mon 12/19/05
48		**Landfill Profiling**	**2 days**	**Fri 12/2/05**
49		Profile non-RCRA soils	2 days	Fri 12/2/05
50		Profile non-RCRA treated soils	2 days	Fri 12/2/05
51		Profile Class II soils	2 days	Fri 12/2/05
52		**Loading, Offhaul & Disposal**	**15 days**	**Tue 12/6/05**
53		Export untreated contaminated soil	5 days	Tue 12/13/05
54		Export Phase I treated soil	5 days	Tue 12/6/05
55		Export Phase II treated soil	5 days	Tue 12/20/05
56		**Backfilling**	**24 days**	**Thu 12/8/05**
57		Approval to backfill	10 days	Wed 12/21/05
58		Place virgin quarry drain rock	3 days	Wed 1/4/06
59		Place import borrow	2 days	Mon 1/9/06
60		Approval to reuse backfill	3 days	Thu 12/8/05
61		Place reuseable import	3 days	Tue 12/13/05
62		**Utility Restoration**	**6 days**	**Wed 1/11/06**
63		Install water line	6 days	Wed 1/11/06
64		Install storm drain line	6 days	Wed 1/11/06
65		**Pavement Restoration**	**4 days**	**Thu 1/19/06**
66		Place aggregate base	2 days	Thu 1/19/06
67		Place AC paving	1 day	Mon 1/23/06
68		Install striping	1 day	Tue 1/24/06
69		**Demobilization**	**16 days**	**Wed 1/4/06**
70		Demolish soil treatment pad & stockpile area	2 days	Wed 1/4/06
71		Remove office trailers	2 days	Fri 1/6/06
72		Remove temporary fencing	1 day	Wed 1/25/06
73		Remove temp signs & K-rail	1 day	Wed 1/25/06
74		Substantial Completion	0 days	Wed 1/25/06



Project: Bldg 1 - ORP Remediation ST
Date: Tue 11/1/05

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

FIGURE 12
Project Schedule

Former ORP/Building 1 Area
Former Oakland Army Base
Oakland, California
November 2005
Project No. 1147.01

APPENDIX A
BATCH TRACKING PROTOCOL FORM

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Treatment Batch Tracking Form

Batch Number (BN):	Date / Check	Signature
Untreated Batch Sample (UBS)		
Name and Date of Collection of Composite UBS:	....	
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Laboratory Analytical Results: • Lead by EPA 6020 extraction TCLP Method 1311 / SW-846	☐	
• pH by EPA 9045:	☐	
UBS is Building 1 Remediation Waste. ☐ Yes ☐ No		

Treatment		
Date of Treatment:.......................... Reagent Application Rate.....................	☐	
Treated Batch Sample (TBS)		
Name and Date of Collection of Composite TBS:		
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Name, Location and Depth of Discrete Sample..............................		
Laboratory Analytical Results • Lead by EPA 6020 extraction TCLP Method 1311 / SW-846: .... < 5mg/l	☐	
• .pH by EPA 9045: .... > 4	☐	
• Moisture ASTM D2216: .... < 50%	☐	
Reduction of Leachable Lead is.......................................≥77%	☐	
Alternative Treatment Standard attained ☐ Yes ☐ No		

Re-treatment ☐

Date of Re-Treatment: ....

Re-treatment Batch Sample (RBS) ☐

Name and Date of Collection of Composite RBS: ....

Name, Location and Depth of Discrete Sample..............................

Name, Location and Depth of Discrete Sample..............................

Name, Location and Depth of Discrete Sample..............................

Name, Location and Depth of Discrete Sample..............................

Laboratory Analytical Results ☐

- Lead by EPA 6020 extraction
  TCLP Method 1311 / SW-846: .... < 5mg/l ☐
- .pH by EPA 9045: .... > 4 ☐
- Moisture ASTM D2216: .... < 50% ☐

Reduction of Leachable Lead is.......................................≥77% ☐

Alternative Treatment Standard attained: ☐ Yes ☐ No

Disposal ☐

State Manifest Document Number:...

Name and ID of designated disposal facility:......................................

Date of Loading, Transportation and Disposal at designated facility's: ....

Sample Description Codes / Sample Number Format: B1BS-001-AAA-BB/CC-0-0.1

Examples:

- ID for the northwest quadrant discrete sample of the treated third batch at a depth of 0 to 1.5 feet is B1BS-003-TBS-DC/NW -0–1.5 at the ORP/Building 1 Area RAP Site.
- ID for the 4-point composite sample of the re-treated third batch is B1BS-003-RBS-CP at the ORP/Building 1 Area Site.

Code	**Batch Sample Description**	**Code**	**Sample Classification (BB)**
BS	Batch Sample	CP	Composite Sample
001	Batch Number	DC	Discrete Sample/Quadrant Location
Code	**Treatment Process Type (AA)**	**Code**	**Quadrant Location (CC)**
UBS	Untreated Batch Sample	NW	Northwest Quadrant
TBS	Treated Batch Sample	NE	Northeast Quadrant
RBS	Re-treated Batch Sample	SW	Southwest Quadrant
		SE	Southeast Quadrant

APPENDIX B
INSTALLATION QUALITY ASSURANCE MANUAL

(Included on Attached CD)

GSE

GSE Geomembranes

Geomembranes ■ Geonets ■ Geocomposites ■ GCLs ■ Geotextiles ■ Concrete Protection ■ Installation Services ■ Fabrications

Installation Quality Assurance Manual

www.gseworld.com

Table of Contents

1.0 Overview

This manual is a guide of the duties and responsibilities for a GSE QA technician.

ASTM Practices that this guide lists include the following and are included separately:

ASTM D-6392 Standard Test Methods For Determining The Integrity Of NonReinforced Geomembrane Seams Produced Using Thermo Fusion Methods

ASTM D-5820 Standard Practice For Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

ASTM D-5641 Standard Practice For Geomembrane Seam Evaluation By Vacuum Chamber

ASTM D-6497 Standard Guide For Mechanical Attachment of Geomembrane to Penetrations or Structures

GRI Standard GM13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GRI Standard GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GRI Standard GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

2.0 Material Delivery

2.01 Upon arrival on site, the GSE QA will do an inventory of materials on the job site.

2.02 Roll numbers of liner, textile, geonet and composite will be logged on the Inventory Check List and cross-referenced with bills of lading (Materials Supplied by GSE).

2.03 Copies of the Inventory Check List and signed Bill of Ladings should be sent to the home office with the QA retaining the originals.

2.04 Any visible damage to roll materials should be noted on the roll and Inventory Check List.

3.0 Earthwork

3.01 The General Contractor is responsible for preparing and maintaining the subgrade. The subgrade should be prepared and maintained per the individual job specifications.

3.02 Subgrade Surface Acceptance Certificate - The GSE Site Manager shall be responsible for assuring that the subgrade surface has been properly prepared for deployment of geosynthetics. If GSE is required to sign a Subgrade Surface Acceptance Certificate, please use the form provided by GSE. Under no circumstances sign off on subgrade that is not suitable for deployment of geosynthetics. Sign the Subgrade Acceptance Certificate only on areas to be covered in one day, preferably after deployment.

3.03 If the subgrade is unacceptable and the GC/Owner directs GSE to deploy over, the GSE Site Manager must have the Owner's representative sign the Deployment by Owner's Direction Over

Unsuitable Subgrade Certificate which will take the place of the Subgrade acceptance Certificate for the particular area being covered.

3.04 Prior to material installation, whenever possible, the QA should measure the area to be covered and compare it to the area used for the bid. An outline of the area including anchor trenches, top of slopes and toe of slopes will be provided by GSE's Drafting department. Use this outline to log actual on-site conditions, i.e....distances between anchor trenches, length of anchor trenches, top of berms, length of slopes and/or any other relevant distances.

Note: Whenever possible distances will be included on the blank outlines. If actual field dimensions have changed or do not match the GSE outline the QA should notify their Supervisor and then the Project Manager, so that quantities can be reassessed to determine the proper amount of material needed for installation. It is important to establish the limits of deployment with all parties. Any changes must be noted and signed off by the Customer's Representative.

4.0 Panel Placement

4.01 Each panel will be assigned a number as detailed below.

4.01a When there is only one layer, panels may be designated with a number only, i.e....
1, 2, 3, 4 etc.

4.01b When two or more layers are required use a letter and number, i.e....
Secondary Liner S1, S2, S3, S4 etc...
Primary Liner P1, P2, P3, P4 etc...
Tertiary Liner T1, T2, T3, T4 etc...

4.02 This numbering system should be used whenever possible. Agreement to a panel numbering system should be made at the pre-construction meeting if possible. However, it is essential that GSE's system and the Owner's Representative/Third Party QA agree. Do not use different systems.

4.03 Panel numbers shall be written in large block letters in the center of each deployed panel. The roll number, date of deployment and length (gross) should be noted below the panel number. All noting should be made so that they are easily visible from a distance. On long panels it is beneficial to write information at both ends.

4.04 Panel Numbers shall be logged on the GSE Panel Placement Log along with the roll number and gross length.

4.05 If there is a partial roll left after deployment it is important to write the last four digits of the roll number several times for future identification, along with the estimated length.

5.0 Trial Welds

5.01 Seaming apparatus shall be allowed to warm up a minimum of 15 minutes before performing trial welds.

5.02 Each seaming apparatus along with GSE Welding Tech will pass a trial weld prior to use. Trial welds to be performed in the morning and afternoon, as a minimum, as well as whenever there is a power shutdown.

5.03 Fusion or wedge welds will always be performed or conducted on samples at least 6' long. Extrusion welds will be done on samples at least 3' long.

Note: Always perform trial welds in the same conditions that exist on the job. Run the trial welds on the ground, not the installed liner. Do not use a wind break unless you are using one on the job.

5.04 Sampling Procedure

5.04a Cut 4 - 1" wide specimens from the trial weld sample. Operating temperatures should be monitored while welding.

5.04b Specimens will always be cut using a 1" die cutter so the peel values may be used for qualitative analysis.

5.04c When cutting coupons from the trial weld samples, the inside and outside tracks on the coupon should be identified to assist in troubleshooting problems in case the weld fails. The outside track will be defined as the track which would be peeled if pulling the overlap exposed in a typical installation, or the seam which is closest to the edge of the top sheet. The inside track is the seam closest to the edge of the bottom sheet.

5.04d Place a small mark on the exposed (Top) overlap to denote the outside track prior to testing trial welds.

5.05 Die Cutter

5.05a Only cut one sample at a time to avoid damaging the die cutter.

5.05b Samples should be free of sand and grit prior to cutting sample.

5.05c Inspect the die edge weekly for nicks, dents or signs of dullness. Dullness of the cutting edge may damage the units.

5.05d Remove die when edge has been dulled and lightly reshape it with a medium hand file. When wear is excessive return it for a replacement die.

5.05e When the cutting board becomes deeply scored and/or interferes with coupon cutting it should be replaced.

5.05d To adjust the depth of the die cut into the cutting board, after replacing the cutting board or sharpening the die, 0.015" washer shims can be added or removed between the cutting ram and the ram extension. Only add shims when cutting is difficult due to lack of depth of cut.

5.06 Trial Weld Testing

5.06a Allow coupons to cool prior to testing. Avoid separating the coupons while hot as failure of the sheet may be initiated and false readings indicated.

5.06b In extreme heat the coupons may need to be cooled, using water or an insulated cooler prior to peel testing. Lab conditions specify 70 degrees (plus or minus 4 degrees) Fahrenheit. Coupon temperatures greater than 70 degrees may result in lowered strengths.

5.06c Visually inspect the coupons for squeeze-out, footprint, pressure and general appearance.

5.06d Each of the 4 coupons will be tested in peel on the field tensiometer at a separation rate of 2" per minute (for HDPE). Shear tests, in addition to the peel tests, will be performed if required by a site-specific QA. Plan.

5.07 Pass/Fail Criteria

5.07a Criteria for passing trial welds will be as follows:

1) Seam must exhibit film tear bond (FTB). Trial welds should have no incursion into the weld.
2) Peel and shear values shall meet or exceed the values listed below for HDPE smooth or textured sheet (@ 2"/min.):

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	81	65	52
60	121	98	78
80	162	130	104
100	203	162	130

3) Peel and shear values shall meet or exceed the values listed below for LLDPE smooth or textured sheet (@ 20"/min.):

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	60	50	48
60	90	75	72
80	120	100	96
100	150	125	120

5.07b Both tracks of fusion welded samples must pass for the trial weld to be considered acceptable. If any of the four coupons fail either due to seam incursion (no FTB) or low strength values, the trial weld must be re-done.

5.07c The GSE QA will give approval to proceed with welding after observing and recording all trial welds.

5.08 Trial Weld Documentation

5.08a All trial weld data will be logged on the GSE Trial Weld log

5.08b When logging fusion welded peel values on the GSE Trial Weld log indicate the values for the outside track first, followed by the inside track

5.08c Speed and temperature settings will be recorded for each machine's trial weld

6.0 Geomembrane Field Seaming

6.01 The seam number takes the identity of the panels on each side. The seam between panels 1 & 2 becomes Seam 1/2. These lengths and seam numbers shall be recorded in the GSE Seam Log.

6.02 Welding Technicians will mark their initials/employee number, machine number, date and time at the start of every seam. Technician should also periodically mark temperatures along the seam and at the end of the seam.

6.03 Approved processes for field seaming and repairing are extrusion welding and fusion welding. All welding equipment shall have accurate temperature monitoring devices installed and working to ensure proper measurement.

6.04 Extrusion welding shall be used primarily for repairs, patching and special detail fabricating and may be used for seaming. The GSE Site Manager shall verify that:

1) equipment in use is functioning properly
2) welding personnel are purging the machine of heat degraded extrudate prior to actual use
3) all work is performed on clean surfaces and done in a professional manner
4) no seaming will be performed in adverse weather conditions

6.05 Fusion welding, shall be used for seaming panels together and is not used for patching or detail work. The GSE Site Manager shall verify that:

1) the equipment used is functioning properly
2) seaming personnel are working in a professional manner and are attentive to their duties
3) no seaming will be performed in adverse weather conditions

6.06 Seam preparation, the welding technician shall verify that:

1) prior to seaming, the seaming area is free of moisture, dust, dirt, sand or debris of any nature
2) the seam is overlapped properly for fusion welding
3) the seam is overlapped or extended beyond damaged areas at least 4" when extrusion welding
4) the seam is properly heat tacked and abraded when extrusion welding
5) seams are welded with fewest number of unmatched wrinkles or "fishmouths"

6.07 No seaming will be performed in ambient air temperatures or adverse weather conditions that would jeopardize the integrity of the liner installation.

7.0 Field Destructive Testing

7.01 Destructive seam tests shall be performed to evaluate bonded seam strength. The frequency of sample removal shall be one sample per 500' of seam, unless specific site specifications differ. Location of the destructive samples will be selected and marked by the QA Technician or third party QA. Field testing should take place as soon as possible after seam is completed.

7.02 Samples should be labeled in numerical order, I.e. DS-1, DS-2 etc....This should carry thru any layers and or multiple ponds, do not start numbering from 1 again. (This is the preferred method)

7.03 The size of samples and distribution should be approximately 12" x 39"(size may vary dependent on Job requirements) and distributed as follows:

7.03a 12" x 12" piece given to QA Technician for field testing.
7.03b 12" x 12" piece sent to Home Office for testing, if required.
7.03c 12" x 12" piece given to third party for independent testing, or archiving.

NOTE: All samples will be labeled showing test number, seam number, machine number, job number, date welded and welding tech number.

7.04 The sample given to the QA Technician in the field shall have ten coupons cut and be tested with a tensiometer adjusted to a pull rate as shown below. All tests shall meet or be greater than the values listed below.

1) Seam must exhibit film tear bond (FTB). Trial welds should have no incursion into the weld.
2) Peel and shear values shall meet or exceed the values listed below for HDPE smooth or textured sheet (@ 2"/min.):

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	81	65	52
60	121	98	78
80	162	130	104
100	203	162	130

3) Peel and shear values shall meet or exceed the values listed below for LLDPE smooth or textured sheet (@ 20"/min.):

Material (Mil)	Shear Strength (PPI)	Fusion Peel (PPI)	Extrusion Peel (PPI)
40	60	50	48
60	90	75	72
80	120	100	96
100	150	125	120

7.05 All trial weld destructive test data will be logged on the GSE Destructive test log.

7.06 When logging fusion welded peel values on the GSE Destructive Test Log, indicate the values for the outside track first, followed by the inside track.

7.08 Test results will be noted in the GSE Destructive Test Log as P (pass) or F (fail).

7.09 If test fails, additional samples will be cut, approximately 10' on each side of the failed test, and retested. These will be labeled A (after) & B (before). This procedure will repeat itself until a sample passes. Then the area of failed seam between the two tests that pass will be capped or reconstructed.

7.10 In lieu of taking an excessive number of samples, the GSE Site Manager may opt to extrusion weld the flap or cap the entire seam and then non-destructively test according to Section 8.0.

8.0 Non-Destructive Testing

8.01 GSE shall non-destructively test all seams their full length using an air pressure or vacuum test. The purpose of this test is to check the continuity of the seam.

8.02 Air testing; the following procedures are applicable to those seams welded with a double-seam fusion welder.

8.02a The equipment used shall consist of an air tank or pump capable of producing a minimum 35 psi and a sharp needle with a pressure gauge attached to insert into the air chamber.

8.02b Seal both ends of the seam by heating and then squeezing together. Insert the needle with the gauge into the air channel, it may be necessary to heat the liner to make this easier. Pressurize the air channel to 30psi. Note time test starts and wait a minimum of 5 minutes to check. If pressure after five minutes has dropped less than 2 psi then the test is successful (Thickness of material may cause variance).

8.02c Cut opposite seam end and listen for pressure release to verify full seam has been tested.

8.02d If the test fails, follow these procedures.

a) While channel is under pressure walk the length of the seam listening for a leak.
b) While channel is under pressure apply a soapy solution to the seam edge and look for bubbles formed by air escaping.
c) Re-test the seam in smaller increments until the leak is found.

8.02e Once the leak is found using one of the proceedures above, cut out the leak area and retest the portions of the seams between the leak areas as per 8.02a to 8.02c above. Continue this proceedure until all sections of the seam pass the pressure test.

8.02f Repair the leak with a patch and vacuum test again.

8.02g All non-destructive tests will be noted in the GSE Non-Destructive Test/Repair log.

8.03 Vacuum testing; the following procedures are applicable to those seams welded with a extrusion welder.

8.03a The equipment used shall consist of an vacuum pumping device, a vacuum box and a foaming agent in solution.

8.03b Wet a section with the foaming agent, place vacuum box over wetted area. Evacuate air from the vacuum box to a pressure suitable to affect a seal between the box and geomembrane. Observe the seam through the viewing window for the presence of soap bubbles emitting from the seam.

8.03c If no bubbles are observed, move box to the next area for testing. If bubbles are observed, mark the area of the leak for repair as per Section 10.0 and retest as per Section 8.03.

Note: If vacuum testing fusion welded seams, the overlap flap must be cut off to perform the tests.

9.0 Defects and Repairs

9.01 Identification; all seams and non-seam areas of the geomembrane lining system shall be examined for defects in the seam and sheet.

9.02 Identification of the defect should be made using the following procedures:

9.02a For any defect in the seam or sheet that is an actual breach (hole) in the liner, installation personnel shall circle the defect and mark with the letter "P" along side the circle. The letter "P" indicates a patch is required.

9.02b For any defect that is not an actual hole, installation personnel shall only circle the defect indicating that the repair method may be only an extruded bead and that a patch is not required.

9.02c Each suspect area that has been identified as needing repair shall be repaired in accordance with this section and Non-Destructively tested as per Section 8.0. After all work is complete, the GSE Site Manager will conduct a final walk-through to confirm all repairs have been completed and debris removed. Only after this final evaluation by GSE's Site Manager and Owner/Agent shall any material be placed over the installed liner.

10.0 Repair Procedures

10.01 Any Portion of the Geomembrane liner system exhibiting a defect which has been marked for repair may be repaired with any one or combination of the following procedures:

1) Patching - used to repair holes, tears, undispersed raw materials in the sheet and dented areas.
2) Grind and Reweld - used to repair small sections of extruded seams.
3) Spot Welding - Used to repair small minor, localized flaws.
4) Flap Welding - Used to extrusion weld the flap of a fusion weld in lieu of a full cap.
5) Capping - Used to repair failed seams.

6) Topping - Application of extrudate bead directly to existing seams.

10.02 The following conditions shall apply to the above methods:

1) surfaces of the geomembrane which are to be repaired shall be roughened
2) all surfaces must be clean and dry at the time of the repair
3) all seaming equipment used in repairing procedures shall be qualified
4) all patches and caps shall extend at least 4" beyond the edge of the defect, and all patches must have rounded corners
5) all cut out holes in liner must have rounded corners, 3" min. radius

11.0 As-Built Drawing Procedures

11.01 Liner Layout

11.01a Submitted As-built Drawings should always be on blank outlines supplied by GSE's Drafting Department. (Phone 281-230-2518 Don Sharkey). When outlines are not available plain paper may be used, but only after permission from GSE's Drafting Department.

11.01b Accuracy to the way seams fit or join.

11.01c Using different colors makes information easier to see. Drawings may be done in ink or pencil, but writing must be neat.

11.01d Do not write so small that it is hard to read.

11.01e Suggested scale is 1" = 40' (Other scales may be used if required).

11.02 Anchor Trenches

11.02a The amount of liner actually in the trench should be noted on the drawing. If amount differs, show all differences and approximate locations.

11.02b If anchor trench is larger than shown on GSE's construction drawings then a written approval should be obtained from the Owner/Agent representative. This should be included in the as-built package.

11.03 Panel & Roll Numbers

11.03a Each panel will be assigned a number as detailed below. When there is only one layer panels may be designate with a number only, i.e.... 1, 2, 3, 4 etc.

11.03b When two or more layers are required use a letter and number, i.e....

Secondary Liner S1, S2, S3, S4 etc...
Primary Liner P1, P2, P3, P4 etc...
Tertiary Liner T1, T2, T3, T4 etc...

11.03c This numbering system should be used whenever possible. Agreement to a panel numbering system should be made at the pre-construction meeting if possible. However, it is essential that GSE's system and the Owner's Representative/Third Party QA agree. Do not use different systems.

11.03d Panel numbers shall be written in large block letters in the center of each deployed panel. The roll number, date of deployment and gross length should be noted below the panel number. All notations should be made so that they are easily visible from a distance. On long panels it is beneficial to write information at both ends.

11.03e Panel Numbers shall be logged on the Daily Report Forms along with the roll number and gross length.

11.03f Whenever possible, roll numbers should be placed next to panel numbers on the field copies of the as-built drawing.

11.04 Seam Lengths

11.04a Every seam length that is not a cross-seam must be noted. This includes rectangles, squares, pies and any other shape (See Fig. A).

11.04b GSE assumes that all regular cross-seams are either 22' or 34' wide, unless they are not full width panels they do not have to be noted on the drawing. Panel widths are measured perpendicularly across the panels.

11.04c All dimensions should be called out in tenths of a foot.

11.05 Tests

11.05a All test markings should conform to the "Legend" on the blank outline.

11.05b It can be assumed that all seam junctions will have a patch, therefore, it is only necessary to note if they don't.

11.06 Seam Numbers

11.06a Since the seam number is drawn from the adjoining panels (I.e. 1/2, 10/11 etc.) there is no need to call out seam numbers on the drawings.

11.06b Each seam must be logged in the Daily Report.

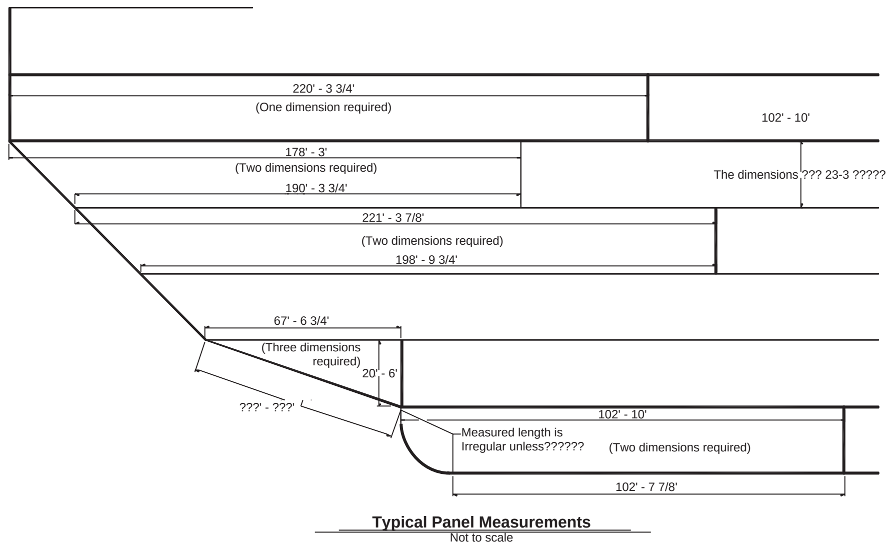


Fig A

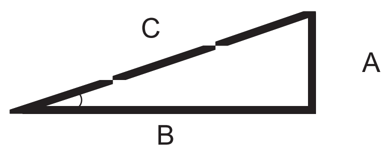
11.07 Miscellaneous

11.07a QA's name should be on all drawings and paperwork.

11.07b Any questions arising in the field about reporting issues may be handled by calling Don Sharkey at 800-435-2008, ext 2518 or 281-230-2518.

12.0 Formulas

12.01 Here are some procedures using trig formulas to enable you to deal with slope corrections concerning seam lengths on as-built drawings in order to do these calculations you will need a calculator that performs trigonomic functions.



A = Rise
B = Base
C = Slope

12.02 Useful Formulas

12.02a rise divided by base = Tangent of the angle

12.02b base divided by cosign of the angle = slope

12.02c slope multiplied by cosign of the angle = base

12.02d rise divided by Tangent of the angle = base

12.03 Slope factors

12.03a Slope factors can be used as a quick method of calculating seam lengths in a flat plan, such as an as-built drawing. Most of the time when field drawings do not fit the outline provided by the Drafting Department it is because actual seam lengths were used instead of lengths calculated with a slope factor. Once you determine the slope factor (a percentage of the actual length) it will probably make field drawings fit the outlines better. As usual, there are always exceptions to this theory.

12.03b To determine a slope factor simply divide the base length by the slope length. Lets use a 3:1 slope as an example. With a base of 100' and a rise of 33.34' the angle of the slope becomes 18.435 degrees. 100' divided by the cosign of 18.435 degrees equals 105.41'. Thus, if you divide 100' by 105.41' you get a slope factor of .9487 or rounded to the nearest one hundredth 0.95.

Now, if you multiply your slope lengths by .95 you will get the actual plan view or paper view length of a seam.

12.04 Typical Slope factors

Slope	Slope Factor	Degrees
2 to 1	0.895	26.565
3 to 1	0.949	18.435
4 to 1	0.970	14.036
5 to1	0.981	11.310
2.5 to 1	0.928	21.802

GSE Panel Placement Log

Project Name: ____________________ Site Manager: ____________________

Location: ____________________ Material: ____________________

Job Number: ____________________ Sheet Thickness: ____________________

Q.A. Technician: ____________________ Smooth: ________ Textured: ________

Panel Number	Roll Number	Deployment Date	Width (Feet)	Length (Feet)	Square Feet Smooth	Square Feet Textured

GSE Seam Log

Project Name: ______________________ Site Manager: ______________________

Location: ______________________ Material: ______________________

Job Number: ______________________ Sheet Thickness: ______________________

Q.A. Techncian: ______________________ Smooth: ______ Textured: ________

Seam Number	Time of Weld	Date of Weld	Type of Weld	Length of Seam	Machine Number	Technician ID Number

GSE Destructive Test Log

Project Name:	Site Manager:	Fusion (ppi)	Extrusion (ppi)
Location:	Material:	Min. Peel	Min. Peel
Job Number:	Sheet Thickness:	Min. Shear	Min. Shear
Q.A. Technician:	Smooth: Textured:		

Sample No.	Date Welded	Seam Number	Technician ID Number	Machine Type & No.	Location	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	FTB Y / N	Pass/ Fail

GSE Non-Destuctive Test / Repair Log

Project Name: ______________ Site Manager: ______________

Location: ______________ Material: ______________

Job Number: ______________ Sheet Thickness: ______________

Q.A. Technician: ______________

Seam Number	Test Date	Technician ID Number	Test Type (A or V)	Air Pressure Test psi start	Air Pressure Test psi finish	Test Result (P or F)	Repair Locations

GSE Trial Weld Log

Project Name: ______________________ Site Manager: ______________________

Location: ______________________ Material: ______________________

Job Number: ______________________ Sheet Thickness: ______________________

Q.A. Technician: ______________________ Smooth: ____________ Textured: ____________

Trial No.	Date of Trial	Time of Trial	Technicians ID Number	Machine Number	Ambient Temp.	Wedge Mass	Speed Preheat	Peel ppi	Peel ppi	Peel ppi	Peel ppi	Shear ppi	Shear ppi	Shear ppi	Shear ppi	FTB Y / N	Pass Fail

Subgrade Surface Acceptance

Date: ____________

Project: ______________________ **Site Manager:** ________________

Project #: ______________________

Location: ______________________ **Partial:** ____________ **Final:** ____________

This document only applies to the acceptability of surface conditions for installation of geosynthetic products. GSE does not accept responsibility for compaction, elevation or moisture content, nor for the surface maintenance during deployment. Structural integrity of the subgrade and maintenance of these conditions are the responsibility of the owner or earthwork contrator.

For GSE Lining Technology, Inc.: ______________________

For Owner / Contractor: ______________________

Acceptance Number: ____________ Area Accepted: ____________ s.f. Total Area Accepted to date: ____________ s.f.

Spark Test Log

Project Name: ______________________ Site Manager: ______________________

Location: ______________________ Material: ______________________

Job Number: ______________________ Sheet Thickness: ______________________

Q.A. Technician: ______________________

Seam or Panel No.	Time of Test	Date of Test	Technician ID Number	Location of Repairs

GSE Lining Technology, Inc.
19103 Gundle Road
Houston, Texas 77073-3598
800-435-2008
281-443-8564
281-875-6010 Fax

Job No.: ____________________
Project: ____________________
Client: ____________________
Bill To: ____________________
____
____
Job Description: ____________________
% Complete of Total Job: ____________

Certificate of Acceptance

Material	Estimated Square feet	Final Quantity/Description

I, the undersigned, duly representative of:
Do hereby take over and accept the work described above from the date hereof and confirm to the best of my knowledge the work has been completed in accordance with the specifications and the terms and conditions of the contract.

Name	Signature	Title	Date

Certificate accepted by GSE Lining Technology, Inc Representative.

Name	Signature	Title	Date

GSE Inventory Check List

Project: ______________________ **Site Manager:** ______________________ Date: ______________

Project #: ____________ **QA Technician:** ______________________ **Page:** ______ of ______

Material	Roll #	Date Used	Material	Roll #	Date Used	Material	Roll #	Date Used	Material	Roll #	Date Used

ASTM D-6392-99

STANDARD TEST METHOD FOR DETERMINING THE INEGRITY OF NONREINFORCED GEOMEMBRANE SEAMS PRODUCED USING THERMO-FUSION METHODS

This standard is issued under the fixed designation D6392: the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (*) indicates an editorial change since the last revision or reapproval

1. Scope

1.1 This test method describes destructive quality control and quality assurance tests used to determine the integrity of geomembrane seams produced by thermo-fusion methods. This test method presents the procedures used for determining the quality of nonbituminous bonded seams subjected to both peel and shear tests. These test procedures are intended for nonreinforced geomembranes only.

1.2 The types of thermal field seaming techniques used to construct geomembrane seams include the following.

1.2.1 Hot Air – This technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond,

1.2.2 Hot Wedge (or Knife) – This technique melts the two geomembrane surfaces to be seamed by running a hot metal wedge between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this kind are made with dual bond tracks separated by a non-bonded gap. These seams are sometimes referred to as dual hot wedge seams or double-track seams.

1.2.3 Extrusion – This technique encompasses extruding molten resin between two geomembranes or at the edge of two overlapped geomembranes to effect a continuous bond.

1.3 The types of materials covered by this test method include the following:

1.3.1 Very Low Density Polyethylene (VLDPE)

1.3.2 Linear Low Density Polyethylene (LLDPE)

1.3.3 Very Flexible Polyethylene (VFPE)

1.3.4 Linear Medium Density Polyethylene (LMDPE)

1.3.5 High Density Polyethylene (HDPE)

1.3.6 Polyvinyl Chloride (PVC)

1.3.7 Flexible Polypropylene (fPP)

Note 1 – The polyethylene identifiers presented in 1.3.1-1.3.5 describe the types of materials typically tested using this test method. These are industry accepted trade descriptions and are not technical material classifications based upon material density.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 638	Test Method for Tensile Properties of Plastics
D 882	Test Methods for Tensile Properties of Thin Plastic Sheeting
D 4439	Terminology for Geotextiles
D 5199	Test Method for Measuring the Nominal Thickness of Geotextiles and geomembranes
D 5994	Test Method for Measuring the Core Thickness of Textured Geomembranes

2.2 EPA Standards:

EPA/600/2-88/052 Lining waste containment and other containment facilities; Appendix N, Locus of break codes for various types of FML seams.

3. Terminology

3.1 Definitions of terms specific to this Standard:

3.1.1 geomembrane, n–an essentially impermeable geosynthetic composed of one or more synthetic sheets.

3.1.2 quality assurance, n–all planned and systematic actions necessary to provide adequate confidence that an item or a facility will perform satisfactorily in service.

3.1.3 quality control, n–The operational techniques and the activities, which sustain a quality of material, product, system, or service that will satisfy given needs; also the use of such techniques and activities.

4. Significance and Use

4.1 The use of geomembranes as a barrier material to restrict liquid migration from one location to another in soil and rock has created a need for a standard test method to evaluate the quality of geomembrane seams produced by thermo-fusion methods. In the case of geomembranes, it has become evident that geomembrane seams can exhibit separation in the field under certain conditions. Although this is an index type test method used for quality assurance and quality control purposes, it is also intended to provide the quality assurance engineer with sufficient seam peel and shear data to evaluate seam quality. Recording and reporting data, such as separation that occurs during the peel test and elongation during the shear test, will allow the quality assurance engineer to take measures necessary to ensure the repair of inferior seams during facility construction, and therefore, minimize the potential for seam separation in service.

5. Apparatus

5.1 Tensile instrumentation shall meet the requirements outlined in Test Method D 638.

5.2 Grip Faces – Grip faces shall be 25mm (1") wide and a minimum of 25mm (1") in length. Smooth rubber, fine serrated or coarse serrated grip faces have all been found to be suitable for testing geomembrane seams.

6. Sample and Specimen Preparation

6.1 Seam Samples – Cut a portion of the fabricated seam sample from the installed liner in accordance with the project specifications. It is recommended that the cutout sample be 0.3m (1') wide and 0.45m (1.5') in length with the seam centered in the middle.

6.2 Specimen Preparation – Ten specimens shall be cut from the sample submittal. The specimens shall be die cut using a 25mm (Nominal 1") wide by a minimum of 150mm (nominal 6") long die. Specimens that will be subjected to peel and shear tests shall be selected alternately from the sample and labeled as shown in Fig. 1. Specimens shall be cut such that the seam is perpendicular to the longer dimension of the strip specimen.

6.3 Conditioning – samples should be conditioned for 40 h in a standard laboratory environment that conforms to the requirements for testing geosysnthetics as stated in Terminology D 4439. Long sample conditioning times typically are not possible for most applications that require seam testing. Prior to testing, samples should be conditioned for a minimum of 1 h at 23 + or - 2° C and a relative humidity between 50 and 70 %.

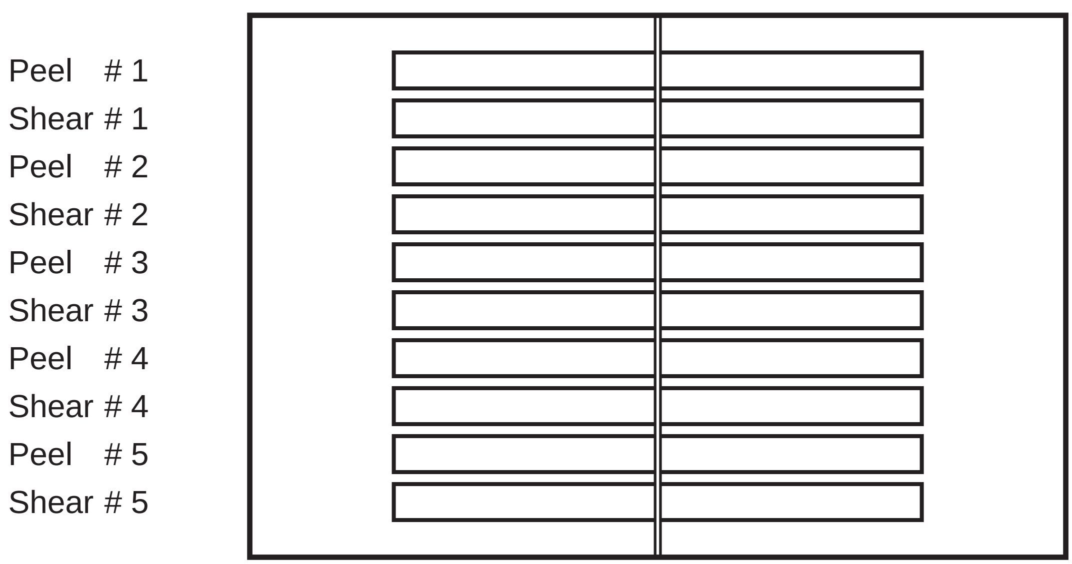


Figure 1 – Seam Sample

7. Destructive Test Methods

7.1 Peel Testing – Subject five specimens to the 90° "T-Peel" test (see Fig. 2). If the tested sample is a dual hot wedge seam, five specimens must be examined for each horizontal track of the seam. Maintaining the specimen in a horizontal position throughout the test is not required. Fully grip the test specimen across the width of the specimen. Grip the peel specimen by securing grips 25mm (1") on each side of the start of the seam bond, a constant machine cross head speed of 50mm (2")/min. for HDPE, LMDPE, and PVC< 500mm (20")/min for LLDPE, VLDPE, VFPE, and fPP. The test is complete when the specimen ruptures.

7.2 Shear Testing – Subject five specimens to the shear test (see Fig. 2). Fully support the test specimen within the grips across the width of the specimen. Secure the grips 25mm (1") on each side of the start of the seam bond, a constant machine cross head speed of 50mm (2")/min. For LMDPE and HDPE, 500mm (20")/min. for fPP, LLDPE, VFPE, VLDPE, and PVC. The test is complete for HDPE and LMDPE once the specimen has elongated 50%. PVC, fPP, LLDPE, VFPE and VLDPE geomembranes should be tested to rupture.

Note 2 – Both peel and shear tests for fPP, LLDPE, VLDPE, and PVC geomembranes have been tested routinely at both 2" and 20" per minute. When conducting seem peel or shear testing for quality control, or quality assurance purposes, or both, it may be necessary to select the manufacturer's recommended testing speed. In the absence of explicit testing speed requirements, follow those recommended in 7.1 and 7.2.

8. Calculations and Observations

8.1 Estimate of Seam Peel Separation – Visually estimate the seam separation demonstrated prior to rupture for peel specimens. The estimate shall be based upon the proportion of linear length of separated bond in the direction of the test, to the length of original bonding to the nearest 25%.

Note 3 – During the thermo-fusion welding process, some of the melted polymer may be shifted to the outside of the weld during the pressing of the geomembrane panels together. This melted polymer is sometimes called "squeeze-out" or "Bleed-out" and is not considered part of the bond. Care must be exercised during estimation of the seam peel separation to segregate the squeeze or bleed out length from the peeled bond length. The reported peel separation shall include the peeled bond length only.

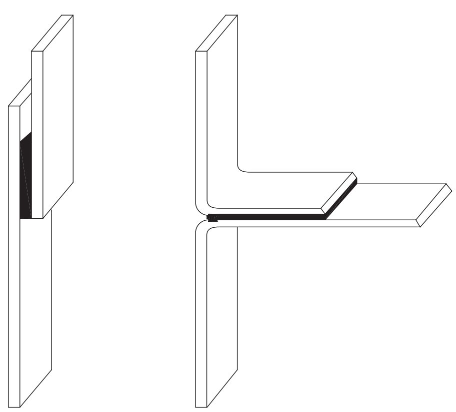


FIG. 2 shear and T-Peel Specimens

8.2 Rupture Mode selection – Determine the locus of break for both the peel and shear specimens as shown in Figs. 3 and 4. The locus of break for shear specimens that do not rupture prior to test end (50% elongation) shall be interpreted as occurring in the membrane that exhibits yielding.

8.3 Shear Percent Elongation – Calculate the percent elongation on shear specimens according to Eq 1. Divide the extension at test end by the original gage length of 25mm (1" and multiply by 100).

$$\text{Elongation} = \frac{L}{L^1} \times 100 \qquad \text{(Equation 1)}$$

where: L = extension at test end, and
L^1 = original gage length

Note 4 – The intent of measuring elongations using this test method is to identify relatively large reductions in typical break elongation values of seam samples. Length is defined as the distance from one grip to the seam edge. Using this definition implies that all strain experienced by the specimen during the shear test occurs on one side of the seam. Of course this assumption is inaccurate, since some strain will occur on each side of the seam, and in the seam area itself, however, it is difficult to make an accurate measurement of the strain distribution which occurs in the specimen during testing. Further, it is not critical to know the exact location of all the strain which occurs during testing but rather to simply identify when significant reductions in elongation (when compared with the typical elongation of a new material) have occurred.

9. Reports

9.1 The report shall include the following information.

9.1.1 Report the individual peel and shear maximum unit tension values in N/mm of width (lb/in.).

Note 5 – If requested, report maximum peel or shear stress. This calculation will require an accurate measurement of thickness for each specimen. These measurements should be made in accordance with Test Method D 5994 for textured geomembranes.

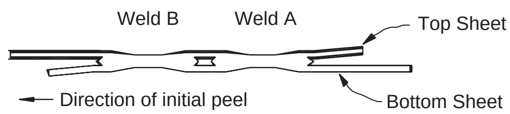
9.1.2 Report the cross head speed used during peel and shear testing.

9.1.3 Report the average of the individual peel and shear sample values recorded.

9.1.4 If the peel or shear specimen does not rupture, report the elongation at the maximum cross-head travel limitation. If the gage length is reduced to less than 25mm (1"), this must be noted in the report.

9.1.5 Report the mode of specimen rupture for peel and shear specimens according to Fig. 3 or Fig. 4.

Schematic of Untested Specimen

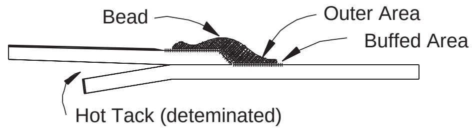


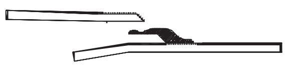
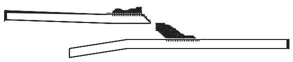
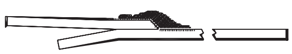
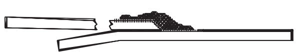
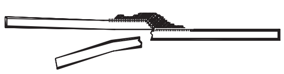
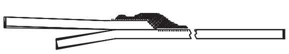
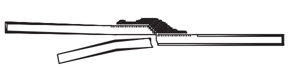
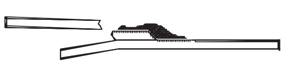
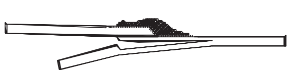
Types of Break	Location of Break Code	Break Description
	AD	Adhesion Failure
	BRK	Breaking in sheeting. Break can be in either top or bottom sheet.
	SE1	Break in outer edge of seam. Break can be in either top or bottom sheet.
	SE2	Break at inner edge of seam through both sheets.
	AD-BRK	Break in first seam after some adhesion failure. Break can be in either top or bottom sheet.
	SIP	Separation in the plane of the sheet. Break can be in either top or bottom sheet.

Figure 3 - Locus of Break Codes for Dual Hot Wedge Seams In Unreinforced Geomembranes tested for Seam Strength in Shear and Peel Modes

Standard Test Method - ASTM D-6392-99

Schematic of Untested Specimen



Types of Break	Location of Break Code	Break Description
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.
	AD2	Failure in adhesion.
	AD-WLD[1]	Break through the fillet.
	SE_1	Break at seam edge in the bottom sheet (Applicable to shear only).
	SE_2	Break at seam edge in the top sheet (Applicable to shear only).
	SE_3	Break at seam edge in the bottom sheet (applicable to peel only).
	BRK1	Break in the bottom sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area.
	BRK2	Break in the top sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area.
	AD-BRK	Break un the bottom sheeting after some adhesion failure between the fillet and th bottom sheet.
	HT	Break at the edge of the hot tack for specimens which could not be bottom sheet.
	SIP	Separation in the plane of the sheet.

(1)Acceptance of AD-WLD breaks may depend on whether test values meet a minimum sp

Figure 4 - Locus of Break Codes for Fillet Weld Seams In Unreinforced Geomembranes tested for Seam Strength in Shear and Peel Modes

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ASTM D-5641-94E1

STANDARD PRACTICE FOR GEOMEMBRANE SEAM EVALUATION BY VACUUM CHAMBER[1]

This standard is issued under the fixed designation D5641: the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of revision. A number in parentheses indicates the year of last reappraval. A superscript epsilon (E) indicates an editorial change since the last revision or reapproval

E1Note – The title was corrected editorially in June 1995.

1. Scope

1.1 This practice covers procedures to perform nondestructive quality control testing described in Practice D 4437 and D 4545 for evaluating the continuity of all types of geomembrane seams using the bubble emission or vacuum chamber method.

1.2 The technique described in this practice is intended for use on geomembrane seams, patches, and defects.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are provided for information only.
geomembrane, forcing together the two surfaces to form a continuous bond,

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 4437 Practice for Determining the Integrity of Field Seams Used in Joining Polymeric Flexible Sheet Geomembranes[2]
D 4439 Terminology for Geotextiles
D 4545 Practice for Determining The integrity of Factory Seams Used in Joining Flexible Sheet Geomembranes[2]
E 515 Test Method for Leaks Using Bubble Emission Techniques[3]

2.2 EPA Standards:

EPA/600/2-88/052 Lining waste containment and other containment facilities, NTIS PB89-129-670[4]
EPA/530/SW-91/051 Inspection Techniques for the Fabrication of Geomembrane Field Seams.

3. Terminology

3.1 Definitions of terms specific to this Standard:

3.1.1 geomembrane, n–an essentially impermeable geosynthetic composed of one or more synthetic sheets. (See Terminology D4439)

3.1.2 seam, n–the connection of two or more pieces of material by mechanical, chemical, or fusion methods to provide the integrity of a single piece of material.

3.1.3 Vacuum chamber, n–a device that allows a vacuum to be applied to a surface.

3.1.3.1 Discussion–In geomembranes, typical seams would include adhesive bonded; bodied chemical fusion welds; chemical fusion welds; dielectric; dual hot wedge; fillet extrusion; flat extrusion; hot air; single hot wedge; and ultrasonic. (See EPA/530/SW-91/051.)

4. Summary of Practice

4.1 The basic principle of this practice consists of creating a pressure differential across a seam and observing for bubbles in a film of foaming solution over the low pressure side, within the vacuum chamber. The vacuum chamber has a viewing port that allows observation of the seal area being tested. The foaming solution is applied to the surface to be tested and the vacuum chamber is placed over the test area. As the chamber is held firmly in place, vacuum is applied. Air leakage through flaws in the test area cause bubbles in the foaming solution that may be observed.

5. Significance and USE

5.1 This Practice is a nondestructive evaluation intended to be used for quality control purposes during factory or field seaming of geomembranes.

5.2 This Practice may also be used to evaluate geomembrane panels for holes that penetrate the entire thickness of material. Limitations on the test practice are that it may not be suitable for uneven or curved surfaces, thick seams in corners, and thin extensible geomembranes.

6. Apparatus

6.1 Vacuum Pump – The vacuum pump shall be fuel or electric powered and capable of sustaining the required vacuum for the duration of the test.

6.2 Vacuum Gage – The vacuum gage shall be capable of registering, as a minimum, to 70 kPa (10psi) in increments of 5 kPa (3/4 psi).

6.3 Calibration and Adjustment–The calibration of the vacuum gage shall be checked and adjusted periodically, and routinely at a minimum of once every twelve months.

6.4 Foaming Solution – The foaming solution shall be pre-mixed with water at a ratio conductive to the formation of bubbles. It shall be dispensed by spray, brush, or any other convenient means. The foaming solution shall be compatible with the geomembrane.

Note 2 – If the component to be tested has parts made of polyethylene or structural plastics, the test fluid must not promote environmental stress cracking (E.S.C.) (See Test Method E 515).

6.5 Vacuum Chamber – The vacuum chamber shall have an open bottom and a clear viewing panel on top. It shall be an appropriate and convenient size and shape, made of rigid materials and equipped with a vacuum gage, valve, and soft pliable gasket around the periphery of the open bottom (See Fig. 1).

Note 3 – Vacuum chamber equipment may be obtained from the suppliers given in Footnote 5. These suppliers are cited only for convenience and no commercial endorsement is expressed or implied by incorporation into this practice.

7. Procedure

7.1 The area of the seam to be evaluated should be clean and free of soil or foreign objects that might prohibit a good seal from being formed between the vacuum chamber and the geomembrane.

7.2 Energize the vacuum pump.

7.3 Wet an area immediately adjacent to and including the geomembrane seam or test area measuring approximately twice the width and length of the vacuum chamber with a foaming solution.

7.4 Place the vacuum chamber over the wet area of the geomembrane such that the gasket is in complete contact with the surface, and the test area is centered under the viewing port.

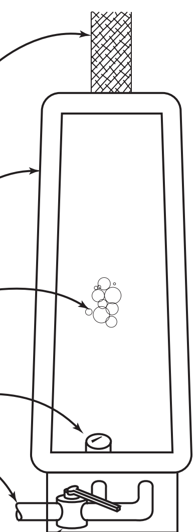

Figure 1 – Vacuum Chamber

7.5 Apply a normal force to the top of the vacuum chamber to effect a seal and open the vacuum valve.

7.6 Ensure that a leak tight seal is created between the vacuum chamber gasket and the geomembrane material. For most cases, a minimum vacuum of 28 to 55 kPa (4 to 8 psi) as registered on the vacuum gage should be appropriate.

7.7 With the vacuum applied, maintain the normal force and observe the geomembrane seam or test area through the viewing port for bubbles resulting from the flow of air through defects in the seam. The vacuum should be held over the test site for a duration of not less than 10 seconds. If the vacuum cannot be held for the minimum10 seconds, the test area should be marked as untested. It is essential that the viewing port remain clean at all times to facilitate unobstructed viewing.

7.8 If bubbles appear on the geomembrane seam, turn the three-way vacuum valve to vent the chamber and remove the vacuum chamber from the seam. The defective area should then be marked for repair.

7.9 If bubbles do not appear through the geomembrane seam or test area within the specified dwell time, turn the vacuum valve to vent the chamber from the seam.

7.10 Move the vacuum chamber to the adjoining portion of the seam or test area overlapping the previously tested area by a distance no less that 10% of the minimum chamber length or at least 50 mm (2"), whichever is the greater and repeat the procedure until the entire seam has been tested.

8. Report

8.1 Report the following information:

8.1.1 Identification of the geomembrane material, including type of polymer, source, thickness, reinforced or nonreinforced sheeting, seaming system used, ambient temperature, seam tested, seam width, date of seam fabrication, and date of seam evaluation, and the results of seam evaluation,

Note 4 – The intent of the form is not to imply that each VCT is to be recorded on said form.

8.1.2 Documentation of the typical vacuum pressure and hold duration and latest pressure gage calibrations.

8.1.3 Identification of the location and approximate size of all defective areas, and

8.1.4 Identification of foaming solution used for the test and if different types were used, the location of use for each type.

9. Keywords

9.1 bubble emission testing; geomembrane; nondestructive testing; seam; testing; vacuum; vacuum chamber.

[1] This practice is under the jurisdiction of ASTM Committee D-35 on Geosynthetics and is the direct responsibility of Subcommittee D 35.10 on Geomembranes. Current edition approved Nov. 15, 1994, published January 1995.

[2] Annual Book of ASTM Standards, Vol. 04.09

[3] Annual Book of ASTM Standards, Vol. 03.03

[4] Available from the superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

[5] Series A 100 Straight Seam Tester supplied by the American Parts and Service Company, 2201 West Commonwealth Avenue, P.O. Box 702, Alhambra, Ca. 91802. Vacuum Chamber Test System as supplied by Sinclair Equipment Company, 6686 A Merchandise Way, Diamond springs, Ca. 95619. Columbine International, Ltd., 54441 Merchant Circle, Placerville, Ca. 95667

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APPENDIX
(Non-mandatory Information)

Testing Agency: ____________________

Date of Test: ____________________ Operator: ____________________

Project Name: ____________________

Installer: ____________________

Job Number: ____________________ Geomembrane Type: ____________

Manufacturer: ____________________ Fabricator: ____________

Seam Width: ____________________ Geomembrane Thickness: ____________

SEAM Factory ____________________ Field ____________

Seam Type Single Hot Wedge ______ Dual Hot Wedge ______ Hat Air ______

Flat Extrusion ______ Fillet Extrusion ______ Dielectric ______

Chemical/Adhesive ______

Vacuum Gage Calibration Date: ____________________

Weather: ____________________ Ambient Temp.: ____________________

Seam Tested	Vacuum Applied	Hold Time Duration	Defects Found	Defects Repaired	Date Seam Accepted

Comments: ____

____

Seams Accepted By: ____________________

Date: ____________________

Figure X1.1 – Evaluation Form

ASTM D-5820-95

STANDARD PRACTICE FOR PRESSURIZED AIR CHANNEL EVALUATION OF DUAL SEAMED GEOMEMBRANES

This standard is issued under the fixed designation D5820: the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of revision. A number in parentheses indicates the year of last reappraoval. A superscript epsilon (E) indicates an editorial change since the last revision or reapproval

[E1]Note – The title was corrected editorially in June 1995.

1. Scope

1.1 This practice covers a nondestructive evaluation of the continuity of parallel geomembrane seams separated by an unwelded air channel. The unwelded air channel between the two distinct seamed regions is sealed and inflated with air to a predetermined pressure. Long length of seam can be evaluated more quickly than by other common nondestructive tests.

1.2 This practice should not be used as a substitute for destructive testing. Used in conjunction with destructive testing, this method can provide additional information regarding the seams undergoing testing.

1.3 This practice supercedes Practice D 4437 for geomembrane seams that include an air channel. Practice D 4437 may continue to be used for other types of seams. The user is referred to the referenced standards, or to EPA/530/SW-91/051 for additional information regarding geomembrane seaming techniques and construction quality assurance.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standard:

D 4437 Practice for Determining the Integrity of Field Seams Used in Joining Polymeric Flexible Sheet Geomembranes[2]

D 4439 Terminology for Geotextiles[2]

D 4491 Test Methods for Water Permeability of Geotextiles by Permittivity[2]

2.2 Other Standard:

CGSB 148.1 #112 Dual Seam Non-Destructive Pressure Testing Method for Geomembranes[3]

EPA/530/SW-91/051 Technical Guidance Document: Inspection Techniques for the Fabrication of Geomembrane Field seams[4]

3. Terminology

3.1 Definitions:

3.1.1 dual seam, n--a geomembrane seam with two parallel welded zones separated by an unwelded air space.

3.1.1.1 Discussion – The dual seam itself can be made by a number of methods, the most common being the hot wedge technique. Other possible methods include hot air and ultrasonic bonding techniques.

3.1.2 geomembrane, – n an essentially impermeable geosynthetic composed of one or more synthetic sheets.

3.1.2.1 Discussion – In geotechnical engineering, impermeable essentially means that no measurable liquid flows through a geosynthetic when tested in accordance with Test Method D 4491.

3.1.3 seam, n – a permanent joining of two or more materials.

3.2 For definitions of other terms, see Terminology D 4439.

4. Summary of Practice

4.1 This practice utilizes a dual seam where an air channel exists between the two welded zones. Both ends of the air channel are sealed and then a pressure gage is attached to the air space. Air pressure is applied and the gage monitored for excessive gage air pressure drop.

4.2 Air pressures used in this practice are related to the thickness, stiffness and material type of the geomembrane.

4.3 The minimum monitoring time is recommended to be 2 minutes following the stabilization of the pressure.

4.4 Maximum allowable loss of air pressure varies depending upon thickness, stiffness and type of material of the geomembrane.

5. Significance and USE

5.1 The increased use of geomembranes as barrier materials to restrict liquid or gas movement, and the common use of dual track seams in joining these sheets, has created a need for a standard nondestructive test by which the quality of the seams can be assessed for continuity and water tightness. The test is not intended to provide any indication of the physical strength of the seam.

5.2 This practice recommends an air pressure test within the channel created between dual seamed tracks whereby the presence of unbonded sections or channels, voids, nonhomogenities, discontinuities, foreign objects, and the like, in the seamed region can be identified.

5.3 This technique is intended for use on seams between geomembrane sheets formulated from the appropriate polymers and compounding ingredients to form a plastic of elastomer sheet material that meets all specified requirements for the end use of the product.

6. Equipment

6.1 Sealing Equipment – appropriate to seal the two ends of the air channel.

6.2 A device is necessary to insert air into the open channel and to allow monitoring its pressure

Note 1 – a sharp hollow needle attached to a properly functioning pressure gage has been used successfully. Other devices may provide equivalent functions.

6.3 Air Pump, either manual or motor driven, capable of generating up to 350 kPa (50 lb/in.2) pressure is necessary. It must be placed on adequate cushion to preclude damage to the geomembrane. A flexible hose is used to connect the pump to the air pressure device. This hose should have a quick connect on its end for disengagement after pressure is supplied to its desired value, that is, the pump is not to be attached while the air pressure is being monitored.

6.4 Knife, capable of cutting or trimming the liner material.

Note 2 – A hook blade knife is recommended. Straight bladed knifes may damage the geomembrane by cutting through the material being trimmed and into the underlying geomembrane.

6.5 Pressure gage, capable of indicating the air pressure in 7 kPa (1 lb/in.2) within the test range.

Note 3 – The gage should be calibrated as specified by the manufacturer, or at a frequency of at least once per year.

7. Procedure

7.1 After the dual track seam is fabricated and the length of seam that is to be evaluated is determined, seal off the two ends of the continuous air channel.

7.2 Connect the pressure gage directly to the air channel.

7.3 Connect an air pump to the pressure gage with a flexible hose via a quick connect and pressurize the air channel to the pressure appropriate for the geomembrane type.

7.4 Remove the flexible hose that connects the air channel to the pressure gage. Following pressure stabilization, observe the air pressure gage for the desired test time. The test time should be a minimum of 2 minutes. Mark the time and pressure of the beginning and end of the test on the geomembrane with a visible marker. The maximum allowable pressure drop may be compared to the maximum allowable value.

7.5 If the pressure does not drop below the maximum allowable value after the specified test period, open the air channel at the end away from the pressure gage. Air should rush out and the pressure gage should register an immediate drop in pressure, indicating that the entire length of the seam has been tested. If this does not happen, either the air channel is blocked or the equipment is faulty, and the test is not valid. Attempt to locate the problem and retest the seam in accordance with the project specifications.

7.6 If the pressure drop is greater than the maximum allowable value after the test period, check the seals of the air channel. Reseal these areas if a leak is noticed and then repeat the entire test.

Note 4 – Leaks around the end seals and air pressure device can usually be located by putting moisture around the suspect area and looking for bubbles.

7.7 If significant changes in the geomembrane temperature occur during pressure testing (for example, cloud cover or other shading), a variation in channel pressure may be recorded due to expansion or contraction of the air channel. If an increase or decrease in temperature is suspected of having caused a pressure variation, repeat the test after the geomembrane temperature has stabilized.

7.8 Any dual seam that cannot be successfully tested using this practice should be marked and tested using another nondestructive testing practice when possible.

8. Report

8.1 The report of a pressurized dual seam test is usually given in the form of a completed form of a completed chart. It should include the following information as a minimum:

8.1.1 Date of test,

8.1.2 Time of test,

8.1.3 Temperature at time of test

8.1.4 Location of test with respect to panel layout plan,

8.1.5 Stabilized air channel pressure,

8.1.6 Duration of test time,

8.1.7 Gage pressure drop during test,

8.1.8 Outcome of test (pass/fail/retest), an

8.1.9 If fail–remedial action is described in detail.

8.2 A form as shown in Fig. 1 includes the above information and may be used for such reporting.

9. Precision and bias

9.1 The precision of this test has not been established.

9.2 The threshold value for accepting seam quality is that value agreed upon by all parties overseeing the installation of the project and is thus the source of bias in this procedure.

Installer Company's Name Page of

Project name Project No. Superintendent

Shop Dwg Seam No.	Field Seam No.	Seam Date	Welder and Seamer I.D. No.	Test Date	Start Pressure (psi)	Start Test (Min)	End Pressure (psi)	End Test (Min)	Air Test Results	Comments	Repair Date	Welder and Gun I.D. No.	Repair Vacuum, Test No.	Seam (Initial Date)

Figure 1 – Report Form for Pressurized Air Channel Test For Dual Seamed Geomembranes

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GRI Standard ASTM D 6497-02

STANDARD GUIDE FOR FOR MECHANICAL ATTACHMENTS OF GEOMEMBRANES TO PENETRATIONS OR STRUCTURES[1]

This standard is issued under the fixed designation D 6497; the number immediately folloing the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A nmber in parentheses indicates the year of last reapproval. A superscript epsilon (^{E}) Indicates an editorial change since the last revision.

1. Scope

1.1 This guide covers procedures that can be employed to mechanically attach fabricated geomembranes to structures, pipes, etc.

1.2 This guide does not address all problems or situations a geomembrane installer or design engineer may face in the attachment of geomembranes to structures, pipes, etc. The sole purpose of this standard guide is to point out typical problems with geomembrane attachments and clearly state objectives of each component of the geomembrane attachments).

1.3 This guide has been generated for geomembrane applications); however, a geomembrane installer or design engineer, or both, may find portions of this guide applicable to other geosynthetics.

1.4 The values stated in SI units are to be regarded as standard, unless other units are specifically given.

1.5 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 EPA Document:

Quality Assurance and Quality Control for Waste Containment Facilities, Technical Guidance Document, United States Environmental Protection Agency, EPA/600/R-93/182, September 19932

3. Terminology

3.1 Definitions:

3.1.1 banding strap, n – a flexible narrow strip of metal, plastic or other material, which compresses the geomembrane around a penetration by acting as a clamp around the penetration.

3.1.2 batten,n – a rigid narrow strip of metal, wood, plastic or other material which distributes the forces to compress the geomembrane against a penetration or structure.

3.1.3 boot, n – a factory or field fabricated geomembrane wrap used to seal around a pipe penetration prior to attachment (see Fig. 1).

3.1.4 clamp, n – a flexible narrow strip of metal, plastic or other material, which compresses the geomembrane against a penetration by tightening the bolt(s) or screw(s) of the clamp (see Fig. 2).

3.1.5 concrete, n – a homogeneous mixture of portland cement, aggregates, and water which may contain admixtures. (C 822)

3.1.6 gaskets, n – a material, which may be clamped between contact surfaces that acts as a static seal. Gaskets are cut, formed, or molded into the desired configuration. They may consist of any of the following construction: one or more plies of a sheet material; composites of dissimilar materials; and materials applied as a bead or other form to one or both mating faces prior to assembly. (F 118)

3.1.7 geomembrane, n – an essentially impermeable geo- synthetic composed of one or more synthetic sheets. (D 4439)

3.1.8 rondel, n – a strip of polymeric material formed to a geometry, which is embedded and secured to a penetration or structure (for example, concrete structure) (see Fig. 3).

3.1.9 sealant – in building construction, a material that has the adhesive and cohesive properties to form a seal. (C 717)

3.1.10 torque, n – a movement (offerees) which produces or tends to produce rotation or torsion. (D 4848)

3.1.11 void space, n – in engineered structures, space(s) between the geomembrane and penetration or structure, which allow liquid or vapor migration, or allow the geomembrane to deform into the space(s) due to overburden pressure. (New, to be balloted under Terminology Committee.

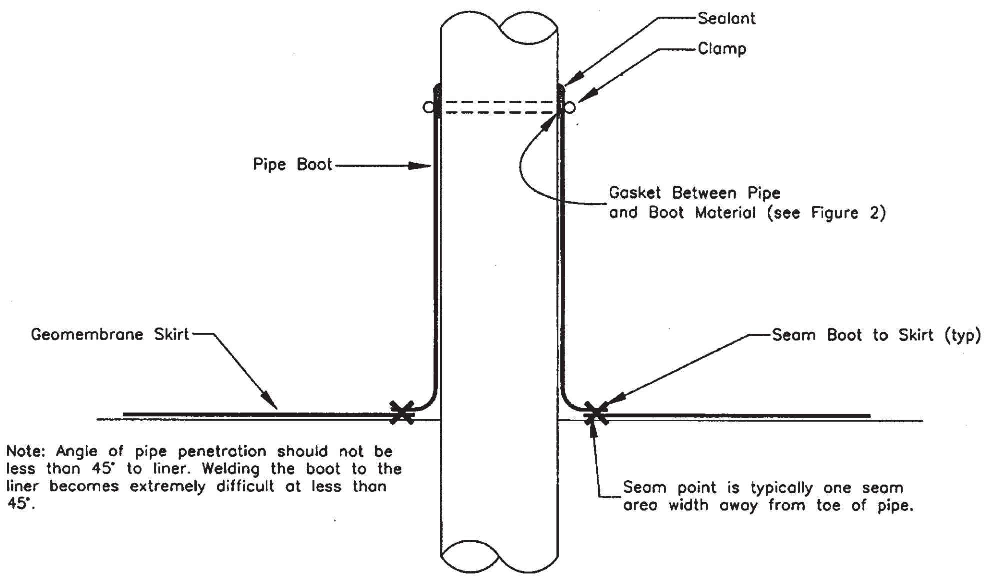


Figure 1 – Pipe Penetration - Perpendicular Face

4. Significance and Use

4.1 This guide attempts to detail specific areas of concern regarding the attachment of geomembranes to structures. Components of the geomembrane attachment are addressed as to the type and use of each component.

4.2 Although this guide does not address all aspects of geomembrane attachments, the user of this guide may note important objectives and design issues of each component of the geomembrane. All these objectives and design issues may or may not be required to obtain an appropriate geoinembranc attachment. By describing these areas of concern, it is hoped that the user of this guide will be able to design geomembrane attachments, develop specifications or construct geomembrane attachments, or both, which fulfill the requirements of its design intent.

5. Types of Connection

5.1 Batten(s) – Battens are commonly used to attach a geomembrane to a smooth, flat surface. Anchor bolts are embedded into the penetration or structure at set locations. A gasket is placed in-line with the bolts to form a seal between the geomembrane and structure. Geomembrane is pushed or forced over the bolts to insure a tight in and then placed against the penetration or structure. The batten, which has holes in it that are in alignment with the bolts, is placed over the geomembrane. Nuts are placed on the bolts and tightened with sufficient torque to compress the geomembrane against the penetration or structure. The geomembrane is held in place by the friction generated by the compression effect of the batten (see Fig. 4).

5.1.1 A compression sealant or gasket can be used between the geomembrane and the penetration or structure or batten, or both. The compression sealant or gasket will limit the migration of liquid or vapor through the batten connection.

5.2 Clamp(s) or Banding Stap(s) – Clamps or banding straps are commonly used to attach a geomembrane to a smooth, round penetration or structure (for example, pipe). The geomembrane is placed around the penetration or structure and welded as close as possible to the circumference of the penetration or structure. A gasket is placed around the penetration or structure at the location of the clamp placement to form a seal between the geomembrane and penetration or structure. The geomembrane is then put in-place and over the gasket. The clamp or banding strap is commonly tightened by applying a torque to a bolt or bolts, a screw or screws, or other mechanical device, which applies a pulling force that decreases the length of the clamp, or banding strap, thereby compressing the geomembrane and gasket to the penetration or structure. The geomembrane is held in place by the friction generated by tightening the clamp or banding strap and compressing the geomembrane against the penetration or structure.

5.2.1 A compression sealant or gasket can be used between the geomembrane and the penetration or structure or clamp, or both. The compression sealant or gasket will limit the migration of liquid or vapor through the clamp connection.

5.3 Welded – Welded connections can be either a solvent weld or heat weld. Heat welding of dissimilar materials can be accomplished as long as both materials are thermoplastic. It is recommended that welding criteria for dissimilar materials be reviewed with the material manufacturer before constructing the attachment.

5.3.1 The welded connections are commonly made to a rondel or pipe (see Fig. 5) composed of similar polymeric material as the geomembrane. The rondel is embedded into the penetration or structure during its construction. For example, rondels are commonly embedded into a concrete structure. The material used for the penetration or structure is allowed to cure before attachment of the geomembrane. The curing time allows the rondel to become secured in the penetration or structure. Once the material used for the penetration or structure has cured sufficiently to reduce the risk of pulling the rondel from the penetration or structure, the geomembrane can be welded to the rondel (see Fig. 3).

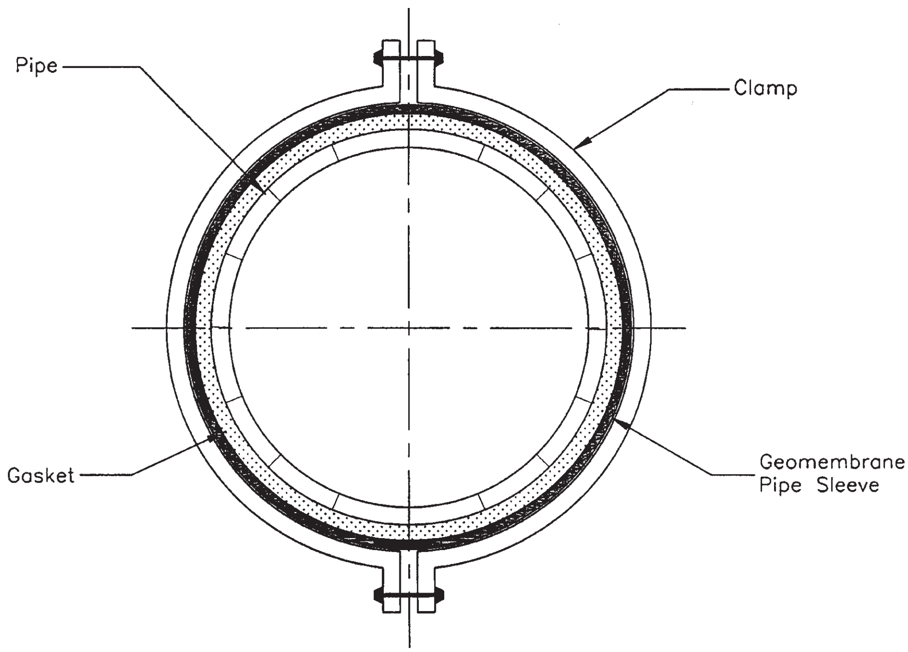


Figure 2 – Clamp Detail

5.3.2 Welding geomembranes to rondels and pipes is similar to welding geomembrane panels together. The geomembrane must be placed flush against the rondel or pipe during the welding process. The geomembrane and rondel or pipe must be clean or prepared, or both, according to the prescribed geomembrane manufacturer's procedure before welding.

5.3.3 Welding the geomembrane to the penetration or structure may provide an attachment that has a lower possibility of leakage. Since the geomembrane is attached directly to the structure, sealants are usually not required. However, special attention should be noted for rondels used for attachment of geomembranes to concrete structures. If several sections or pieces of rondels are required to construct an attachment, spaces or gaps between the individual sections or pieces could occur during their embedment and during the curing of the concrete. This would especially occur for rondels made of polymeric material that expands and contracts according to the temperature of the concrete during the curing process. Sealants may be required to fill the spaces or gaps between the rondels to further limit the migration of liquid or vapor through the batten connection.

5.3.4 Pro-fabrication of the complete rondel attachment before placement into the concrete is recommended. The pre-fabricated rondel is composed of welded sections or pieces of rondels, thereby eliminating the possibility of gaps between sections or pieces on rondels after the concrete cures.

5.4 Bonded – Bonded connections commonly require the use of an adhesive to construct the attachment. The use of an adhesive allows the geomembrane to be attached to dis-similar material. The adhesive used must be compatible with both the geomembrane and the surface material of the penetration or structure. The application and curing of the adhesive should not significantly deteriorate the strength of the geomembrane or the material surface of the penetration or structure beyond the design requirements of the attachment.

5.4.1 The geomembrane and the surface of the penetration or structure should be clean and prepared according the adhesive manufacturer's and geomembrane manufacturer's recommendation.

5.4.2 Bonding the geomembrane to the penetration or structure may provide an attachment, which has a lower possibility of leakage. Since the geomembrane is attached directly to the structure, sealants are usually not required.

6. Types of Structures

6.1 Concrete – Concrete structures that require attachment of geomembranes include, but are not limited to, pads, floors, walls, tanks, manholes, and pylons. The use of battens, clamps or banding strips, or boning can attach a geomembrane to concrete structures. When attaching a geomembrane to any concrete structure, consider each critical concern detailed in Section 7.

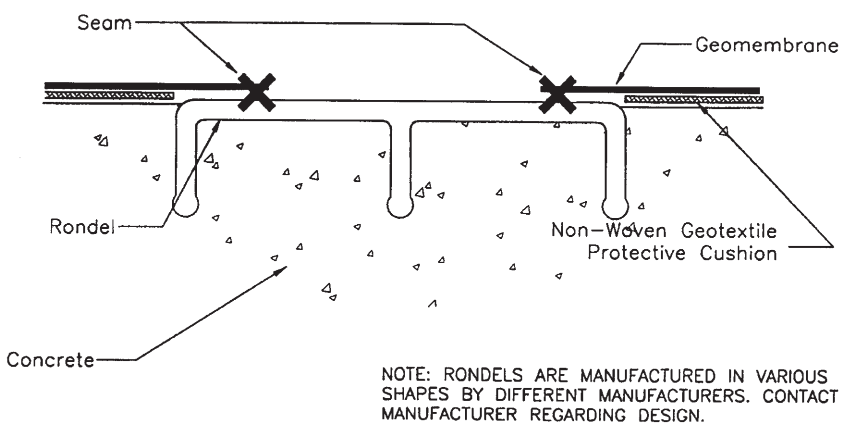


Figure 3 – Rondel Connection

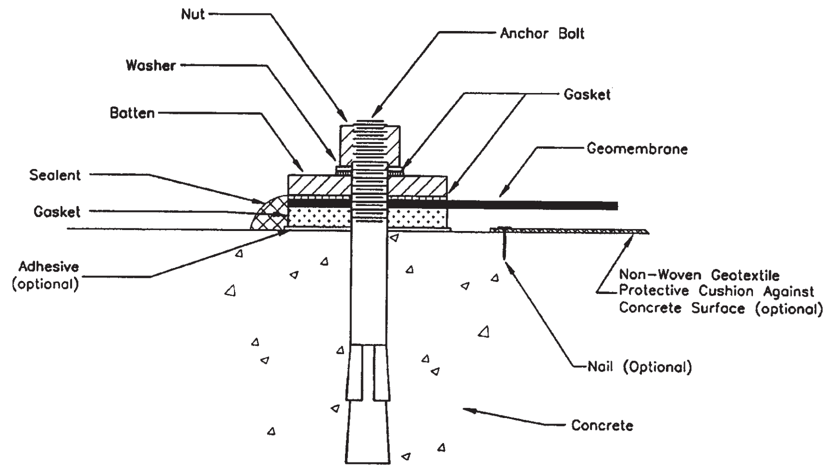


Figure 4 – Anchor Bolt Geomembrane Connection

6.2 Metal – Metal structures that require attachment of geomembranes include, but are not limited to, pads, floors, walls, pipes, and tanks. The use of battens, clamps or banding strips, can attach a geomembrane to metal structures. When attaching a geomembrane to any metal structure, consider each critical concern detailed in Section 7.

6.3 Pipe – Pipe structues can be composed of concrete, metal or polymer. Clamps, banding strips, solvent weld, or heat weld can attach a geomembrane to pipe structures. The attachment of a geomembrane to a pipe structure should consider critical concerns detailed in Section 7.1, 7.3, 7.4, 7.5, and 7.6..

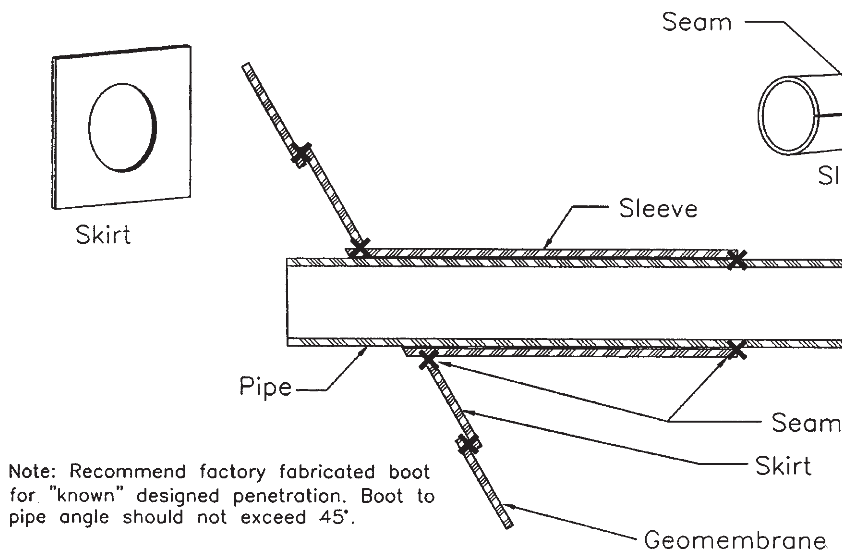


Figure 5 – Pipe Boot

7. Critical Areas for the Protection of the Geomembrane

7.1 Surface Characteristics – The surface of the structure for which the geomembrane is to be attached should be constructed or formed to limit damage to the geomembrane. This is particularly important in cases where the geomembrane will be pressed against the structure. Irregularities in the structure surface could cause stress points in the geomembrane, thereby, allowing portion(s) of the geomembrane to yield at a lower load than its design application. If a structure cannot be constructed or formed without irregularities, then a protective layer should be placed between the structure and the geomembrane (see Fig. 4).

7.2 Edges of Structures—Edges or corners of structures should be rounded to limit possible damage to the geomembrane. A protective layer can be constructed or placed over the edge or corner to protect the geomembrane.

7.3 Large Voids Under Geomembrane – Large voids under the geomembrane can cause deformation and stress in the geomembrane and geomembrane seams if, under pressure or load, the geomembrane is forced into the void(s). Large voids should be filled or bridged to stop the geomembrane and geomembrane seams from becoming overly stressed (see Figs. 6 and 7).

7.4 Settlement Around Structures— If a geomembrane is to be connected to a structure and placed over an area which may settle at a greater or lesser rate than the structure, the design engineer or geomembrane installer should take precautions to limit settlement around the structure. If settlement around the structure cannot be avoided, then the design engineer should design a flexible connection to the structure that considers settlement and alleviates the stresses, which could occur due to settlement.

7.5 In-Plane Attachment – The geomembrane should be placed in parallel or "in-plane" with the structure or penetration to be attached. The geomembrane should lie flat against the surface of the structure or penetration for a sufficient distance prior to the geomembrane being placed "out of plane" of the structure or penetration. This is to avoid bridging within attachment, pulling away from the structure, or stresses within the geomembrane during the placement of the batten or clamp, or both.The attached figures show the geomembrane being parallel or "in-plane" to the structure or penetration as part of the attachment.

7.6 Protection from Bolts, Battens, Clamps – The installation of geomembrane over bolts, battens or clamps should be done with a protective layer placed between the geomembrane and these items to prevent damage to the geomembrane by these items (sec Fig. 8).

7.7 Cushion/Sealant Between Geomembrane and Structure, Geomembrane and Battens, Geomembrane and Clamps/Bands – A cushion/sealant should be placed between the geomcmbrane and the structure, between the geomembrane and the batten or geomembrane and the clamps/band to protect the geomembrane and allow for a seal between the geomembrane and the structure, batten, or clamp/band.

8. Critical Items tor Strength ot Attachment

8.1 Cleanliness – The area of the attachment should be cleaned to remove loose debris, dirt, oils, or other foreign material(s), or all of these, that could hinder the ability to develop a strong attachment of the geomembrane to the structure. It is recommended that the only materials in the area of the attachment should be the clean geomembrane, structure, and type of connection used to perform the attachment.

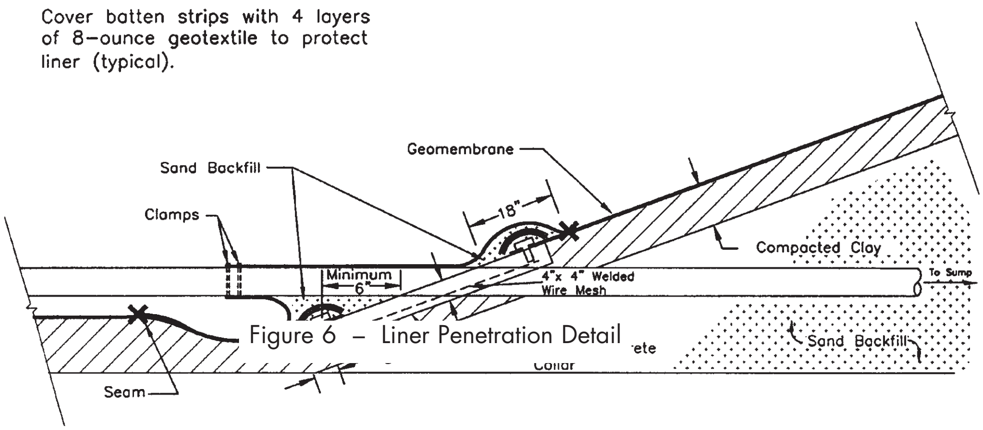


Figure 6 – Liner Penetration Detail

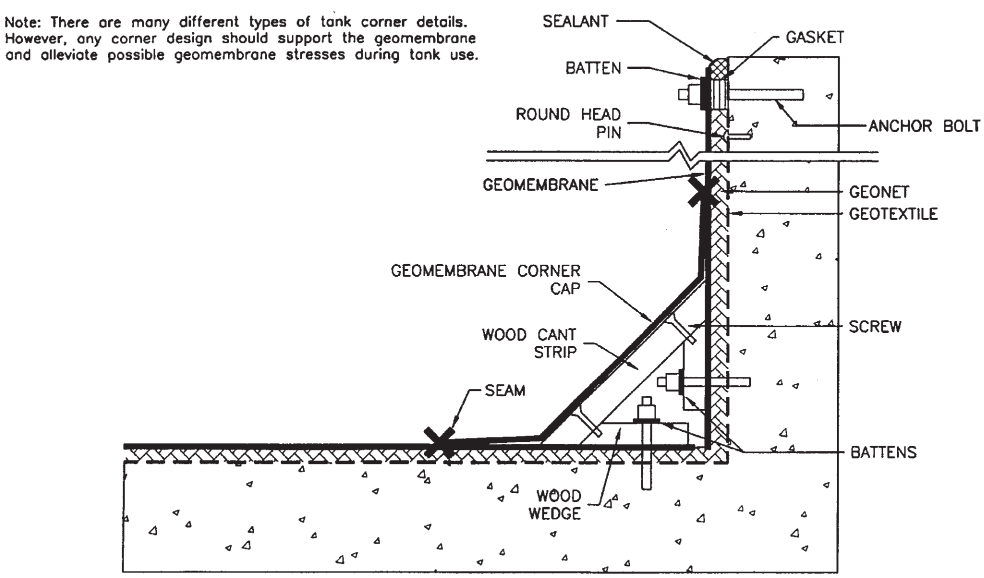
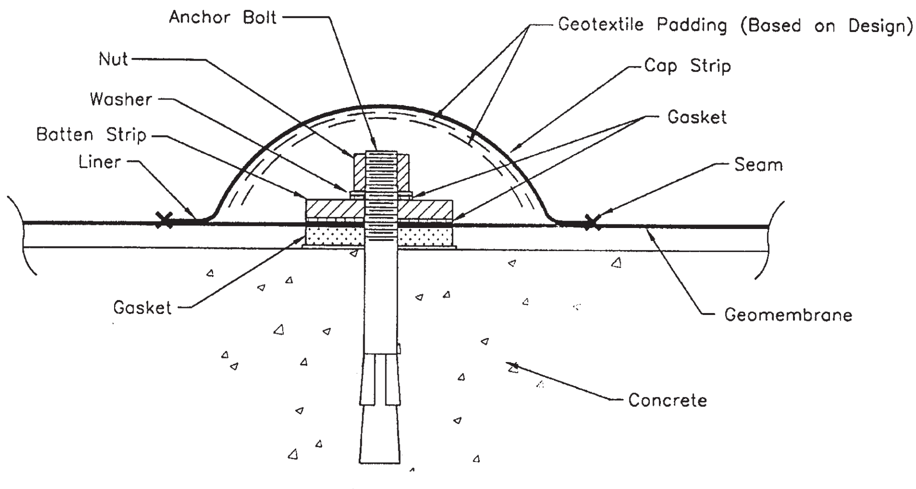


Figure 7 – Tank Corner Detail

8.2 Type of Attachment:

8.2.1 Battens:

8.2.1.1 Type of Batten Material – Battens can be made of wood, metal, or polymer. The batten must remain functional for the design life of the attachment and be chemically resistant with the fluids or vapors to which it will be exposed. The batten should also be made of a material that will not crack, fracture, break or warp during or after the batten has been fastened to the structure. If a hydraulic seal is a mandatory requirement of the attachment, the batten should have sufficient rigidity to maintain a seal between the designed spacing of the bolts.



NOTE:

1. A length of bolt extending above the clamping nut must be limited to 2-3 threads exposed when tightening or torquing is finished.
2. An "Acorn" can be used to round off top of bolt. However, the number of threads exposed above the batten strip is critical to assure tightening of the nut.

Figure 8 – Batten Attachment with Cap Strip

8.2.1.2 Type of Bolts – The bolts should be made of a material capable of fulfilling the design life of the attachment. The bolts should be made of a material capable of withstanding the torque required to secure the batten to the structure. Wedge anchors holes must be carefully drilled to assure the grip necessary to develop the pullout resistance required for sealing the gasket and geomembrane to the structure. Adhesive (epoxy) anchors, properly installed, may provide a more reliable alternative to wedge anchors.

8.2.1.3 Number of Bolts, – The battens should have a sufficient number of bolts to secure the batten and geomembrane to the structure without damaging the sealants and geomembrane. If the batten is used to attach the geomembrane to a vertical wall, the number of bolts should be sufficient to develop sufficient strength to support the geomembrane.

8.2.1.4 Bolt Spacing – a seal is a mandatory requirement of the attachment, the bolt spacing should be sufficient to allow the batten and geomembrane to be secured to the structure without warping of the batten and limiting the functionality of the sealant or geomembrane between bolts, or both.

8.2.1.5 Torque – Sufficient torsional force should be applied to the bolt to secure the batten and geomembrane to the structure without damaging the batten, geomembrane, sealant, or structure.

Note – The amount of torque applied to the bolt can be compromised by the bolt thread condition, cleanliness (dirt in threads), nicks in the threads and calibration of the torque wrench. If a gasket of known thickness and hardness (for example, durometer value) is used as a sealant, a predetermined reduction of thickness of (the gasket (10 to 15%) may provide a reliable method of applying the required compression force on the clamps or battens.

8.2.2 Clamps – Clamps can be made of polymer or steel. The clamp must remain functional for the design life of the attachment. The clamp should have sufficient strength and rigidity to fasten the geomembrane to the structure by applying sufficient torque to the bolts or force on the clamps. The clamp should not be capable of elongating over time and, thereby, weakening the attachment. If a seal is a mandatory requirement of the attachment, the clamp should not be over tightened to (the extent of damaging the sealant.

8.2.3 Gaskets – The chemical compatibility of the gasket material should be considered.

8.2.4 Rondels – The rondel should be embedded into the concrete to a depth to allow a smooth transition between the concrete surface and top of the rondel. The concrete should be allowed to cure to the design requirements or according to the specifications before attaching of the gcomembrane to the rondel.

Note- 2 – The user should contact the rondel manufacturer regarding specific rondel designs and installation procedures.

8.3 Void Space – The size and number of voids around or near the attachment should be limited. If voids cannot be eliminated, it is recommended that the voids be filled to limit the ability of the geomembrane to deform into the void(s). Deformation into the voids by the geomembrane may increase the possibility of weakening and damaging the attachment.

9. Factory Pro-Fabricated Boots, Corners and Edyes

9.1 Many manufacturers or installers, or both, produce factory pre-fabricated boots, corners and edges that ease the geomembrane installation process and, thereby, increase the quality of the finished project. Boots, corners, and edges pre-fabricated in a controlled factory environment are considered to be of higher quality than the field fabricated, which are subject to ambient field conditions. Some manufacturer's factory pre-fabricated boots are designed to allow for field testing for increased construction quality control/assurance or reduce void space within the boot attachment, or both. Factory pre-fabricated corners and edges can reduce the overlapping of geomembrane and increase the integrity of the geomembrane attachment. Edges and corners can also be pre-fabricated of thicker stronger geomembrane material for these critical areas.

10. Shape, Size, and Proximity of Penetrations

10.1 Shape – The shape of the penetration should be considered in the design and/or installation of the geomembrane attachment. For example the design to use a geomembrane under a building constructed on top of pilings or within a reservoir with support columns, many pilings or columns have a square or odd shape. The attachment of the geomembrane to one or more of these pilings or columns could be a difficult installation that requires excessive labor and materials to complete. The difficulty of the attachment may also decrease the ability to obtain a sufficient liquid/vapor barrier. Changing the shape of the penetration may alleviate this problem. By requiring the pilings or columns to be round is a solution. Another alternative is to pour a concrete collar around the piling or column a the location of the attachment. Clamps or banding straps (see 5.2) can then be used to achieve a quick and sufficient attachment.

10.2 Size – Thc size of the penetration can create significant difficulty constructing a geomembrane attachment. Usually penetrations smaller than 50 mm (2 in.) in diameter are difficult to construct. It is recommended that the designer or installer review alternatives that will allow the size of the penetration to increase and reduce the difficulty of the attachment. Fig. 9 is an example of such an alternative. In this figure, several small pipes and/or wires are brought through a larger pipe, which allows a less difficult attachment. The annular space between the pipes and/or wires is grouted, thus creating a liquid/vapor barrier.

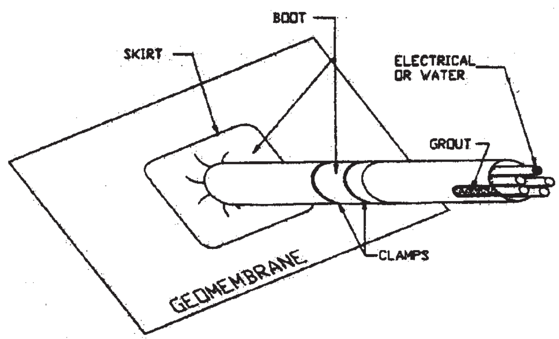


Figure 9 – Pipe Penetration Detail

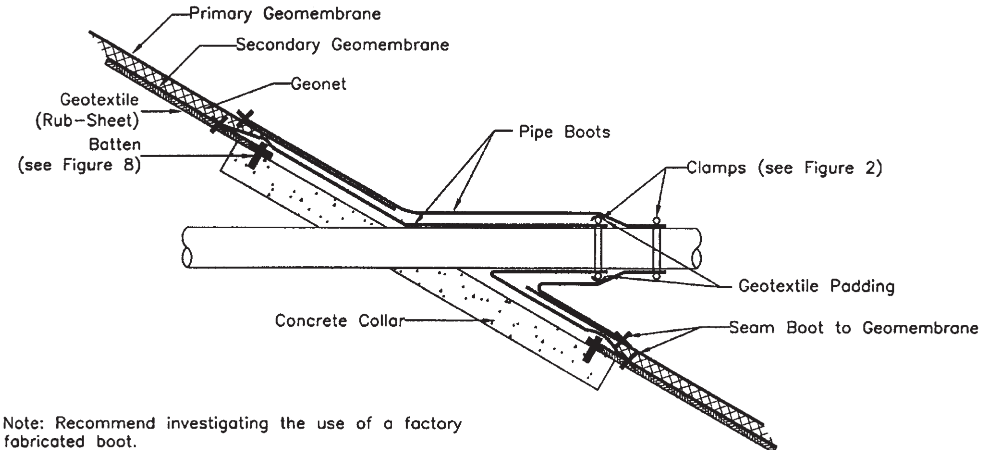
10.3 Proximity – The proximity of each penetration should be considered in developing a geomembrane attachment. Penetrations in close proximity to each other can be difficult to construct an attachment. The flexibility of the geomembrane, the working environment, size of penetration, and type of attachment should be reviewed as part of the design and installation. If possible, it is recommended that penetrations should be spaced a minimum of 1 m (3 ft) a part from each other. If this is not possible other alternatives should be investigated. Fig. 9 shows how several penetrations were brought together to make one penetration.

11. Examples of Attachments

11.1 This guide includes Figs. 10-15 that show examples of various geomembrane attachments to penetrations or structures. These figures do not address all problems or situations a geomembrane installer or design engineer may face in the attachment of geomembranes to structures, pipes, etc. The purpose of the figures is to illustrate typical attachments. It is the geomembrane installer or the design engineer or both, that must determine the design intent of the geomembrane attachment and design/construct the attachment to meet that design intent. Additions or deletions of various items noted within the figures may be required to meet the design intent. It is the responsibility of the geomembrane installer or design engineer, or both, to make that determination. See Appendix XI.

12. Keywords

12.1 attachment; batten; concrete; gasket; geomembrane; geotextile; rondel; sealant; structure



Note: Recommend investigating the use of a factory fabricated boot.

Figure 10 – Pipe Penetration - Double Layer System with Collar

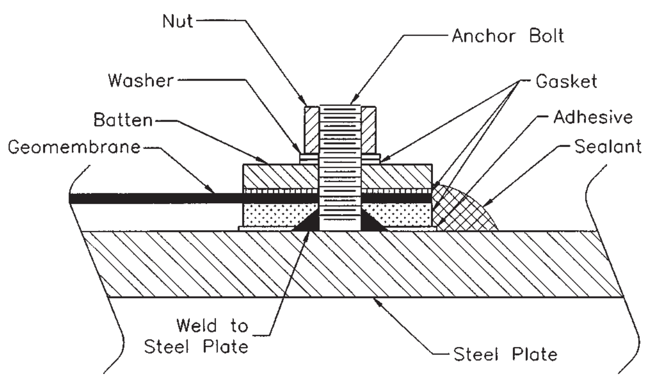
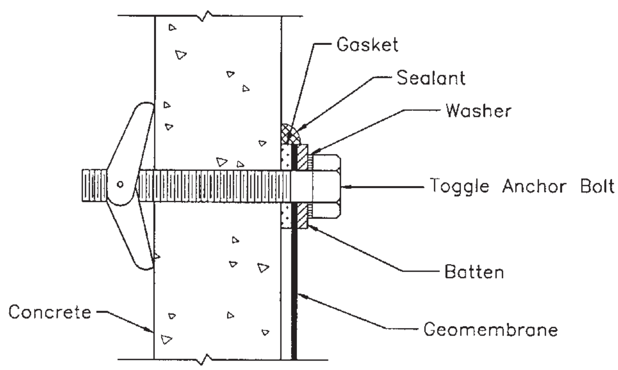


Figure 11 – Batten Attachment to Steel Plate



Note: This type of anchor is normally used in a masonry wall or thin concrete wall.

Figure 12 – Batten Attachment

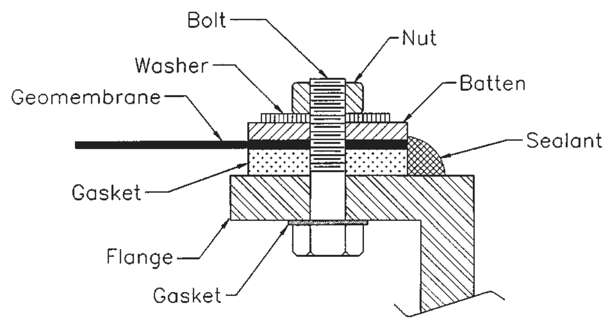


Figure 13 – Batten Attachment to Flange

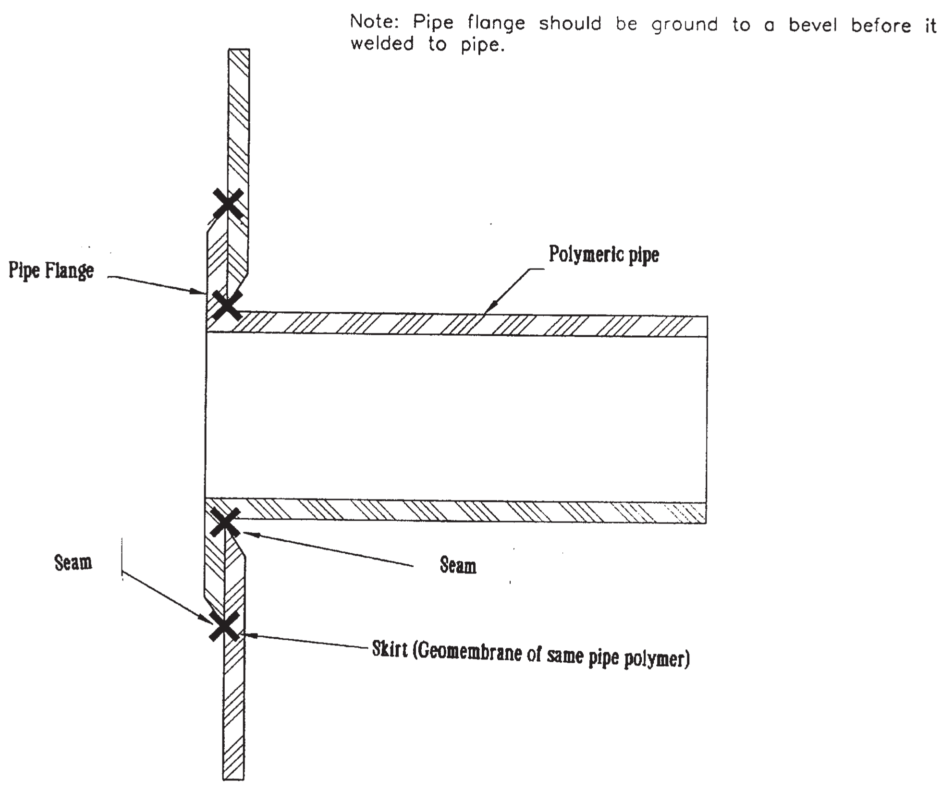


Figure 14 – Pipe Boot

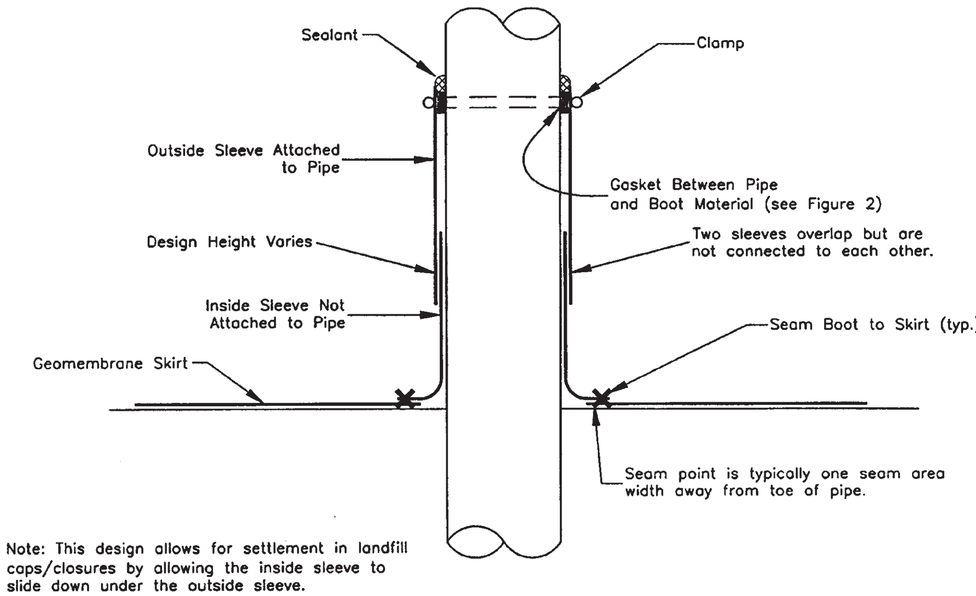


Figure 15 – Slip Boot Detail

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GRI Standard GM 13*

STANDARD SPECIFICATION FOR TEST PROPERTIES, TESTING FREQUENCY AND RECOMMENDED WARRANTY FOR HIGH DENSITY POLYETHYLENE (HDPE) SMOOTH AND TEXTURED GEOMEMBRANES

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1.0 Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for test indicated, may be necessary under conditions of a particular application.

1.5 This specification also presents a recommended warrant which is focused on the geomembrane material itself.

1.6 The recommended warrant attached to this specification does not cover installation considerations which is independent of the manufacturing of the geomembrane.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

2. Referenced Documents

2.1 ASTM Standards:

D 638	Test Method for Tensile Properties of Plastics
D 792	Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004	Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505	Test Method for Density of Plastics by the Density-Gradient Technique
D 1603	Test Method for Carbon Black in Olefm Plastics
D 3895	Test Method for Oxidative Induction Time of Polyolefms by Thermal Analysis
D 4218	Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D5199	Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397	Procedure to Perform a Single Point Notched Constant Tensile Load -(SP-NCTL) Test: Appendix
D 5596	Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefm Geosynthetics
D 5721	Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885	Test method for Oxidative Induction Time of Polyolefm Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994	Test Method for Measuring the Core Thickness of Textured Geomembranes

2.2 GRI Standards:

GM10	Specification for the Stress Crack Resistance of Geomembrane Sheet
GM 11	Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device
GM 12	Measurement of the Asperity Height ofTextured Geomembranes Using a Depth Gage

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3.0 Definitions

Manufacturing Quality Control (MQC) – A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications. ret. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) – A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project. ref. EPA/600/R-93/182

Formulation, n – The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types ofresin(s), additives and carbon black.

4.0 Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter. Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5.0 Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HOPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 4: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height ofTextured Sheet

Note 5: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 6: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:

- UV Fluorescent Light Exposure
- Asperity Height Measurement

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 7: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

11. Warranty

11.1 Upon request of the purchaser in the contract or order, a manufacturer's warrant of the quality of the material shall be furnished at the completion of the terms of the contract.

11.2 A recommended warranty for smooth and textured HDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.

11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.

Note 8: If a warrant is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

APPENDIX “A”

TYPICAL HDPE GEOMEMBRANE WARRANTY

ENGLISH UNITS

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value 30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	Testing Frequency (minimum)
Thickness (min. ave.)	D5199	nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density mg/l (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,00 lb
Tensile Properties *(1)* (min. ave.)	D 6693 Type IV								20,000 lb
• yield strength		63 lb/in.	84 lb/in.	105 lb/in.	126 lb/in.	168 lb/in.	210 lb/in.	252 lb/in.	
• break strength		114 lb/in.	152 lb/in.	190 lb/in.	228 lb/in.	304 lb/in.	380 lb/in.	456 lb/in.	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
• break elongation		700%	700%	700%	700%	700%	700%	700%	
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb	45,000 lb
Stress Crack Resistance *(2)*	D5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI-GM10
Carbon Black Content (range)	D 1603 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)*									200,000 lb
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C *(5), (6)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance *(7)*	GM 11								
(a) Standard OIT (min. ave.)	D 3895	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 5885	50%	50%	50%	50%	50%	50%	50%	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC) UNITS

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - mils (min. ave.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
Density (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 11 kN/m 20kN/m 12% 700%	 15 kN/m 27 kN/m 12% 700%	 18 kN/m 33 kN/m 12% 700%	 22 kN/m 40 kN/m 12% 700%	 29 kN/m 53 kN/m 12% 700%	 37 kN/m 67 kN/m 12% 700%	 44 kN/m 80 kN/m 12% 700%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	240 N	320 N	400 N	480 N	640 N	800 N	960 N	20,000 kg
Stress Crack Resistance *(2)*	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI GM-10
Carbon Black Content - %	D 1603 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	 D 3895 D 5885	 N. R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(3) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(7) The condition of the test should be 20 hr. UV cycle at 75ºC followed by 4 hr. condensation at 60ºC.
(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ENGLISH UNITS

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value 30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	Testing Frequency (minimum)
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) *(1)*	GM 12	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	every 2nd roll *(2)*
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (min. ave.) *(3)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 63 lb/in. 45 lb/in. 12% 100%	 84 lb/in. 60 lb/in. 12% 100%	 105 lb/in. 75 lb/in. 12% 100%	 126 lb/in. 90 lb/in. 12% 100%	 168 lb/in. 120 lb/in. 12% 100%	 210 lb/in. 150 lb/in. 12% 100%	 252 lb/in. 180 lb/in. 12% 100%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	45 lb	60 lb	75 lb	90 lb	120 lb	150 lb	180 lb	45,000 lb
Stress Crack Resistance *(4)*	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI GM10
Carbon Black Content (range)	D 1603 *(5)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	20,000 lb
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(7)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	200,000 lb
Oven Aging at 85°C *(7), (8)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(9)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	GM11 D 3895 D 5885	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥ 5 mils

(2) Alternate the measurement side for double sided textured sheet

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(4) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC UNITS)

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) *(1)*	GM 12	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	every 2nd roll *(2)*
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) *(3)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 8 kN/m 12% 100%	15 kN/m 10 kN/m 12% 100%	18 kN/m 13 kN/m 12% 100%	22 kN/m 16 kN/m 12% 100%	29 kN/m 21 kN/m 12% 100%	37 kN/m 26 kN/m 12% 100%	44 kN/m 32 kN/m 12% 100%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance *(4)*	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI GM10
Carbon Black Content (range)	D 1603 *(5)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	note *(6)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(7)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(7)*, *(8)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(9)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(11)*	GM11 D 3895 D 5885	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	 N.R. *(10)* 50%	per each formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 0.18 mm, and lowest individual reading must be ≥ 0.13 mm
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ADOPTION AND REVISION SCHEDULE FOR HDPE SPECIFICATION PER GRI-GM13

"Test Properties, Testing Frequency and Recommended Warrant for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.

GRI Standard GM14

SELECTING VARIABLE INTERVALS FOR TAKING GEOMEMBRANE DESTRUCTIVE SEAM SAMPLES

1. Scope

1.1 This guide is focused on selecting the spacing interval for taking destructive seam samples of field deployed geomembranes as a particular job progresses based on an installers ongoing record of pass - or - fail testing.

Note 1 - While subjective at this time, the guide is most applicable to large geomembrane seaming projects, which require more than 100 destructive seam samples based upon the typical sampling strategy of 1 destructive sample per 150 m (500 ft).

1.2 This guide is essentially applicable to production seams. Caution should be exercised in using the guide for projects that involve complex geometries, multiple penetrations, or extreme weather conditions.

1.3 The primary target audiences for this guide are construction quality assurance (CQA) organizations, construction quality control (CQC) organizations, facility owner/operators and agency regulators having permitting authority.

1.4 The outcome of using the guide rewards good seaming performance resulting from a record of passing destructive seam tests. It also penalizes poor seaming performance resulting from a record of excessively failing seam tests.

1.5 This guide does not address the actual seam testing procedures that are used for acceptance or failure of the geomembrane seam test specimens themselves. Depending on the type of geomembrane being deployed one should use ASTM D4437, D3083, D751 and D413 for testing details in this regard. The project-specific CQA plan should define the particular criteria used in acceptance or failure.

1.6 An appendix is offered using control charts, which is intended to be of assistance to geomembrane installers, i.e., construction quality control (CQC) organizations, to identify salient aspects of good and poor seaming performance.

2. Referenced Documents

2.1 ASTM Standards:

D4437 Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes

D3083 Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining

D751 Method of Testing Coated Fabrics

D413 Test Methods for Rubber Property - Adhesion to Flexible Substrate

2.2 Other Standards:

ANSI/ASQC Z1.4 [1993]

Sampling Procedures and Tables for Inspection by Attributes

3. Summary of Guide

3.1 Use of this guide requires the establishment of an anticipated geomembrane seam failure percentage (ranging from 1 to 8%) and an initial, or start-up, sampling interval.

Note 2 - The value of anticipated failure percentage is an important consideration. It dictates each decision as to a possible increase or decrease in interval spacing from the preceding value. The percentage itself comes from historical data of the construction quality assurance (CQA) organization or regulatory agency. It is related to a number of factors including criticality of installation, type of geomembrane, type of seaming method and local ambient conditions.

The actual value is admittedly subjective and should be made known in advance to the geomembrane installer before bidding the project. Use of an unrealistically low value of anticipated failure percentage, e.g., < 1.0%, will likely result in field difficulties insofar as decreased sampling intervals are concerned. Conversely, use of an unrealistically high value of anticipated failure percentage, e.g., > 8.0%, will likely result in very large sampling intervals and quite possibly sacrifice the overall quality of the seaming effort.

3.2 The guide then gives the procedure for establishing the initial number of samples needed for a possible modification to the start-up sampling interval. This is called the initial batch. Based upon the number of failed samples in the initial batch, the spacing is increased (for good seaming), kept the same, or decreased (for poor seaming).

3.3 A second batch size is then determined and the process is continued. Depending on the project size, i.e., the total length of seaming, a number of decision cycles can occur until the project is finished.

3.4 It is seen that the number of samples required for the entire project is either fewer than the start-up frequency (for good seaming); the same as the start-up frequency (for matching the initial anticipated failure percentage); or more than the start-up frequency (for poor seaming).

4. Significance and Use

4.1 Construction quality assurance (CQA) and construction quality control (CQC) organizations, as well as owner/operators and agency regulators can use this guide to vary the sampling interval of geomembrane seam samples (i.e., the taking of field samples for destructive shear and peel testing) from an initial, or start-up, interval. This initial interval is often 1 destructive seam sample in every 150 m (500 ft) of seam length.

4.2 The guide leads to increasing the sampling interval for good seaming practice (hence fewer destructive samples) and to decreasing the sampling interval for poor seaming practice (hence additional destructive samples).

4.3 Use of the guide should provide an incentive for geomembrane installers to upgrade the quality and performance of their field seaming activities. In so doing, the cutting of fewer destructive samples will lead to overall better quality of the entire liner project, since the patching of previously taken destructive samples is invariably of poorer quality than the original seam itself.

Note 3 - It is generally accepted that field patching of areas where destructive samples had been taken using extrusion fillet seaming is less desirable than the original seam, which was made by hot wedge welding.

4.4 Control charts are illustrated in Appendix A, which can be used by geomembrane installers and their construction quality control (CQC) personnel for improvement in overall job quality and identification of poorly performing seaming personnel and/or equipment.

5. Suggested Methodology

Using the concepts embodied in the method of attributes, the following procedure is based on adjustments to sequential sampling.

5.1 Typical Field Situation - In order to begin the process, a project-specific total seam length must be obtained from the installers panel (roll) layout plan. Also, an initial, or start-up, sampling interval must be decided upon. From this information the total number of samples that are required based on the start-up sampling interval can be obtained.

Example 1 - A given project has 54,000 m (180,000 ft) of field seaming. The start-up sampling frequency is 1 sample per 150 m (500 ft). Therefore, the total number of samples required if the start-up interval is kept constant will be:

$$\frac{54{,}000}{150} = 360 \text{ Samples}$$

5.2 Determination of Initial Batch Size - Using the table shown below, the initial batch size from which to possibly modify the start-up sampling interval is obtained.

TABLE 1. BATCH SIZE DETERMINATION, AFTER ANSI/ASQC Z1.4 [1993]

No. Of Required Samples Based on Initial	No. Of samples Needed (Batch Size)
Or Modified Sampling Interval	To Determine Subsequent Sampling Interval
2-8	2
9-15	3
16-25	5
26-50	8
51-90	13
91-150	20
151-280	32
281-500	50
501-1200	80
1201-3200	125

Example 1 (cont.) - For 360 samples, a batch size of 50 is necessary. As production seaming progresses, these 50 samples are tested (either as they are taken or in a batch) and the number of failures is determined.

5.3 Verification of Start-Up Sampling Interval - A sampling table is now used which separates the number of failures within this initial batch size into three categories: a relatively low number of failures (where the sampling interval can be increased), the anticipated number of failures (where the sampling interval is maintained), or a relatively high number of failures (where the sampling interval should be decreased). Table 2 provides this information that is based upon the operation characteristic (OC) curves of Appendix B.

Example 1 (cont.) - Assuming an anticipated failure percentage of 2% (recall Note - 2), Table 2 results in the three categories shown below:

- 0 or 1 failure out of 50; the sampling interval can be increased
- 2 or 3 failures out of 50; the sampling frequency should remain at 1 sample per 150 m (500 ft)
- 4 or more failures out of 50; the sampling interval should be decreased

TABLE 2. SAMPLING TABLE CONTAINING THE NUMBER OF FAILED SAMPLES TO BE USED FOR INTERVAL

Sampling Interval Modification, see Appendix B for details

No. Of Required Samples Based on Initial or Modified Sampling Interval	No. Of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval	Anticipated Failure Percentage*							
		1%		2%		3%		4%	
		I	D	I	D	I	D	I	D
2-8	2	0	1	0	1	0	1	0	1
9-15	3	0	1	0	1	0	2	0	2
16-25	5	0	1	0	1	0	2	0	2
26-50	8	0	1	0	1	0	2	0	2
51-90	13	0	1	0	2	0	2	0	3
91-150	20	0	2	0	3	1	3	1	4
151-280	32	0	2	1	3	1	4	2	5
281-500	50	0	3	1	4	2	5	3	6
504-1200	80	1	4	2	6	3	7	5	9
1201-3200	125	2	5	4	7	5	9	7	11

No. Of Required Samples Based on Initial or Modified Sampling Interval	No. Of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval	Anticipated Failure Percentage*							
		5%		6%		7%		8%	
		I	D	I	D	I	D	I	D
2-8	2	0	1	0	1	0	2	0	2
9-15	3	0	2	0	1	0	2	0	2
16-25	5	0	2	0	1	0	3	0	3
26-50	8	0	3	0	1	1	3	1	4
51-90	13	1	4	1	2	1	4	1	5
91-150	20	1	5	2	3	2	5	2	6
151-280	32	2	6	3	3	3	7	4	7
281-500	50	4	7	4	4	5	9	6	10
504-1200	80	6	10	7	6	8	12	9	14
1201-3200	125	9	13	10	7	12	17	13	19

No: *To be selected by CQA, owner or regulatory organizations
I = Increase the sampling interval if the number of failed samples found in the batch does not exceed the tabulated value.
D = Decrease the sampling interval if the number of failed samples found in the batch equals or exceeds the tabulated value.

5.4 Modification of Start-Up Sampling Interval - Depending upon the outcome of the previous section, the start-up sampling interval may be modified to a new value which will then require a new batch size to verify the modification. The process is then continued until the project is finished. Two examples will be provided using the above sampling tables both with anticipated failure percentages of 2.0%: Example 2 illustrates good seaming, and Example 3 illustrates poor seaming.

Example 2 - Using the same project seam length and start-up sampling frequency as in the previous example assume that the start-up batch of 50 samples in the previous example had 2-failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size from Table 1 is again 50 samples, see Table 3. Table 3(a) is in S.I. units and Table 3(b) is in English units. Now assume in the second batch there are no failures. This allows the sampling interval to be increased, e.g., to 1 sample in 180 m (600 ft). From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 3(a) illustrates that 265 samples (or 266 samples when using the English units in Table 3(b)) are necessary. Note that by using a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Also note that the maximum sampling interval was fixed at 310 m (1000 ft).

Note 4 - This example, and the following one, use a changing sampling interval of +/- 20% from the previous value. That is, when good seaming allows for an increase in sampling interval; the progression being from 150, 180, 215, 260 to 310 m (500, 600, 720, 850 to 1000 ft), respectively. A maximum interval of 310 m (1000 ft) is recommended, but clearly this value is at the discretion of the organizations involved. Conversely, poor seaming requires a decrease in sampling interval, the progression being from 150, 120, 100, 80 to 65 m (500, 400, 320, 250 to 200 ft), respectively. A minimum interval of 65 m (200 ft) is recommended, but clearly this decision is also at the discretion of the organizations involved

Table 3(a) - Results of Example 2 (in S.I. Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

Batch Number	Sampling Interval (m)	No. Of Remaining Samples Required	Batch Size	Cumulative Distance (m)	Number of Failures	Decision Made
1	150	360	50	7500	2	Stay
2	150	310	50	15000	0	Increase
3	180	217	32	20760	0	Increase
4	215	155	32	27640	2	Stay
5	215	123	20	31940	1	Stay
6	215	103	20	36240	0	Increase
7	260	68	13	39620	1	Stay
8	260	55	13	43000	0	Increase
9	310	35	8	45480	0	Stay
10	310	27	8	47960	0	Stay
11	310	19	5	49510	0	Stay
12	310	14	3	50440	0	Stay
13	310	11	3	51370	0	Stay
14	310	8	2	51990	0	Stay
15	310	6	2	52610	0	Stay
16	310	4	2	53230	0	Stay
17	310	2	2	53850	0	Done

Total Number of tests per 54,000 m of seam project = 265

Table 3(a) - Results of Example 2 (in English Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

Batch Number	Sampling Interval (Ft)	No. Of Remaining Samples Required	Batch Size	Cumulative Distance (Ft)	Number of Failures	Decision Made
1	500	360	50	25000	2	Stay
2	500	310	50	50000	0	Increase
3	600	217	32	69200	0	Increase
4	720	155	32	92240	2	Stay
5	720	123	20	106640	1	Stay
6	720	103	20	121040	0	Increase
7	850	68	13	132090	1	Stay
8	850	55	13	143140	0	Increase
9	1000	35	8	151140	0	Stay
10	1000	27	8	159140	0	Stay
11	1000	19	5	164140	0	Stay
12	1000	14	3	169140	0	Stay
13	1000	11	3	172140	0	Stay
14	1000	8	2	174140	0	Stay
15	1000	6	2	176140	0	Stay
16	1000	4	2	178140	0	Stay
17	1000	2	2	179140	0	Done

Total Number of tests per 180,000 ft of seam project = 266

Example 3 - Using the same project seam length and start-up sampling frequency as Example 1, assume that the start-up batch of 50 samples had 3- failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size is again 50 samples as it was with Example 2, see Table 4. Table 4(a) is in S.I. units and Table 4(b) is in English units. Now assume in the second batch there are 2-failures. The decision is to again continue at a 1 destructive sample in 150 m (500 ft) sampling interval. From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 4 illustrates that 412 samples are necessary. Note that by a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Furthermore, a good seamer (as illustrated in Example 2) would only have had to take 265 samples.

Table 4(a) - 150Results of Example 3 (in S.I. Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

Batch Number	Sampling Interval (m)	No. Of Remaining Samples Required	Batch Size	Cumulative Distance (m)	Number of Failures	Decision Made
1	150	360	50	7500	3	Stay
2	150	310	50	15000	2	Stay
3	150	260	32	19800	2	Stay
4	150	228	32	24600	3	Decrease
5	150	245	32	28440	3	Decrease
6	150	256	32	31640	1	Increase
7	150	186	32	35480	1	Increase
8	150	123	20	38480	2	Stay
9	150	103	20	41480	1	Stay
10	150	83	13	43430	2	Decrease
11	150	88	13	44990	2	Decrease
12	150	90	13	46290	1	Stay
13	150	77	13	47590	1	Stay
14	150	64	13	48890	1	Stay
15	150	51	13	50490	0	Increase
16	150	32	8	51150	1	Stay
17	150	24	5	51750	1	Decrease
18	150	23	5	52250	0	Increase
19	150	15	3	52610	0	Increase
20	150	9	2	52910	1	Decrease
21	150	9	2	53150	1	Decrease
22	150	11	3	53210	0	Increase
23	150	7	2	53390	0	Increase
24	150	5	2	53510	0	Increase
25	150	3	2	53750	0	Done

Total Number of tests per 54,000 m of seam project = 412

Table 4(b) - Results of Example 3 (in English Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

Batch Number	Sampling Interval (Ft)	No. Of Remaining Samples Required	Batch Size	Cumulative Distance (Ft)	Number of Failures	Decision Made
1	500	360	50	25000	3	Stay
2	500	310	50	50000	2	Stay
3	500	260	32	66000	2	Stay
4	500	228	32	82000	3	Decrease
5	400	245	32	94800	3	Decrease
6	320	266	32	105040	1	Increase
7	400	187	32	117840	1	Increase
8	500	124	20	127840	2	Stay
9	500	104	20	137840	1	Stay
10	500	84	13	144340	2	Decrease
11	400	89	13	149540	2	Decrease
12	320	95	13	153700	1	Stay
13	320	82	13	157860	1	Stay
14	320	69	13	162020	1	Stay
15	320	56	13	166180	0	Increase
16	400	35	8	169380	1	Stay
17	400	27	5	171380	1	Decrease
18	320	27	5	172980	0	Increase
19	400	18	3	174180	0	Increase
20	500	12	2	175180	1	Decrease
21	400	12	2	175980	1	Decrease
22	320	13	3	176140	0	Increase
23	400	10	2	176780	0	Increase
24	500	6	2	177140	0	Increase
25	600	5	2	177980	0	Done

Total Number of tests per 54,000 m of seam project = 412

5.5 Summary

This guide illustrates by means of hypothetical examples how a CQA and/or CQC organization can modify the sampling interval for taking destructive samples from a geomembrane-seaming project. It is based on the method of attributes that are common to statistical control methods. The methodology uses sequential sampling to proceed from one decision to the next until the project is complete.

The result in using this guide for the above purpose is to reward good seaming performance by taking fewer destructive samples, and to penalize poor seaming performance by taking additional destructive samples. In the example illustrations, good seaming resulted in taking 265 samples (versus 360), or a decrease of 26% from the originally set constant interval of 1 sample per 150 m (500 ft). Conversely, poor seaming resulted in taking 412 samples (versus 360), or a 14% increase in the originally set constant interval of 1 sample per 150 m (500 ft.) of seam length.

Appendix A - General Principles of Control Charts

In order to control a production process, like the field seaming of geomembranes, it is necessary to identify and quantify characteristics that reflect the quality of the product. Such quality characteristics can be either discrete or continuous variables. For example, the number of pinholes in a sheet of geomembrane is a discrete variable. Variation in the thickness of a sheet of geomembrane, however, is considered to be a continuous variable.

Whether quality characteristics are discrete or continuous, variability in the observed values is unavoidable. In the theory of control charts, this variation is considered due to either random (common) or assignable (special) causes, Wadsworth (1989) and Deming (1982). Random causes are generally smaller, uncontrollable influences that cannot be removed from the process without fundamental changes in the process itself. An assignable cause, however, is an influence considered to be significant, unusual, and capable of being removed form the process. Such causes may be due to human error, variation in raw materials, or the need for machine adjustment.

An important tool used to reduce process variation is the use of control charts. When using control charts, control limits are used to determine whether the variability of the statistic over time appears to be due to random variation only, or if an assignable cause is present. In other words, the purpose of control charts is to establish a "statistical control" of the assignable causes of variation within of a process.

The control chart generally used to monitor conforming or non-conforming data, called attributes, is the p-chart, where "p" stands for the proportion of non-conforming items in the entire population. In the case of inspecting the quality of the seams of field-deployed geomembranes, the p-value would be the historic failure percentage of the installer.

Suppose we have m subgroups (e.g., m different operators, or m different welding machines, or m working days, etc.) of varying sample sizes n_1, n_2, ..., nm. The number of non-conforming (failed) samples in the ith subgroup is Di, i =1, 2, ..., m, so the proportion of non-conforming items (failure rate) in the ith subgroup is as follows:

$$\hat{P}_i = \frac{D_i}{n_i} \quad 1 = 1,2,...,m \tag{A1}$$

For the p-chart, the values of pi are plotted against the subgroup number with a control limit, CL, set at the following:

$$CL = p + 3 \left[\frac{p(1-p)}{n} \right]^{1/2} \tag{A2}$$

Where $\bar{n} = \frac{1}{m}\sum_{i=1}^{m} n_i$ = average sample size.

Two examples follow:

Example A1 - Assume that a seaming project is expected to take 25-days for completion, i.e., m=25. The installer has a historic data indicating that the company's average failure percentage is 2.0%. As the work progresses, the number of destructive seam samples and the respective numbers of failures are listed in tabular form as shown in the following table. Note that the daily failure rates, i.e., , are also shown in the table. The control chart of this project can now be developed.

Subgroup No. (days)	No. Of destructive samples	No. Of failures in subgroup	Failure Percentage P
1	12	0	0.000
2	14	0	0.000
3	9	0	0.000
4	7	0	0.000
5	13	1	0.077
6	15	0	0.000
7	19	1	0.053
8	13	0	0.000
9	14	1	0.071
10	9	0	0.000
11	17	1	0.059
12	16	0	0.000
13	7	0	0.000
14	22	1	0.045
15	18	0	0.000
16	16	0	0.000
17	15	0	0.000
18	16	0	0.000
19	14	0	0.000
20	16	0	0.000
21	22	1	0.045
22	18	0	0.000
23	16	0	0.000
24	9	0	0.000
25	13	1	0.077

Solution: From Equation (B2), the control limit is calculated as follows:

$$CL=0.02+3\left[\frac{0.02(1-0.02)}{360/25}\right]^{1/2}=0.13$$

The control chart can now be obtained by plotting the subgroup failure rate against the subgroup number (i.e., days) along with the control limit, CL = 0.13. The results are shown in the following figure, note that the 2.0% historic failure rate is also shown.

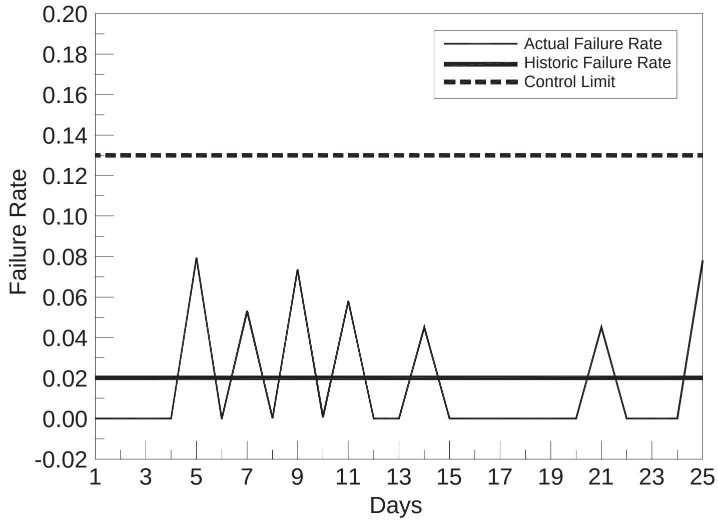


Figure A1 – The Resulted Control Chart of Example A-1.

As seen in the above control chart, the entire 25-day record of the failure rate of this project falls below the control limit set on the basis of the installer's 2.0% historic failure rate. That is to say, the variations in the daily failure record were due to random causes only and no assignable cause was identified. The above control chart indicates that no corrective action is necessary. This is an example of good seaming control.

Example A2 - For a similar size seaming project and historic record (i.e., 2% failure rate) as presented in Example A-1, a second installer has a poorer destructive seam record as shown in the following table. The control chart of this particular situation can also be developed.

Subgroup No. (days)	No. Of destructive samples	No. Of failures in subgroup	Failure Percentage
1	12	1	0.083
2	14	0	0.000
3	9	1	0.111
4	7	0	0.000
5	13	1	0.077
6	15	1	0.067
7	19	3	0.158
8	13	2	0.154
9	14	1	0.071
10	9	0	0.000
11	17	0	0.000
12	16	1	0.063
13	7	1	0.143
14	22	2	0.091
15	18	1	0.056
16	16	2	0.125
17	15	0	0.000
18	16	1	0.063
19	14	0	0.000
20	16	1	0.063
21	22	2	0.091
22	18	1	0.056
23	16	3	0.188
24	9	0	0.000
25	13	1	0.077

Solution: Since the historic failure rate is the same as shown in Example A-1.A new control chart can now be obtained by plotting the subgroup failure rate against the subgroup number (i.e., days) along with the control limit, CL = 0.13. The results are shown in the following figure. Again, the 2.0% historic failure rate is also shown.

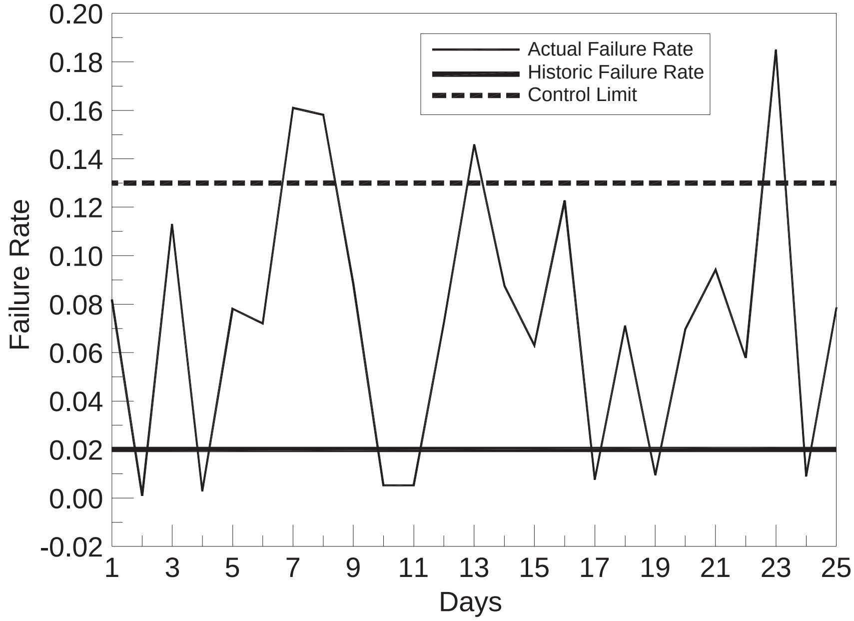


Figure A2 - The Resulted Control Chart of Example A-2.

As seen in the above control chart, the daily failure rates at day 7, 8, 13 and 23 exceed the control limit set on the basis of the installer's 2.0% historic failure rate. That is to say, there are possible assignable causes on those days. From the standpoint of construction quality control, the installer should check the record on those days, identify the cause(s) of such variations, and take necessary corrective actions. This is an example of poor seaming.

GM 14 - Appendix B - The Selection of the "I" and "D" Values

In this appendix, the procedure used for selecting the "I" and "D" values listed in Table 2 is presented. The required background, e.g., the concept of sampling risk and the operating characteristics (OC) curves, are briefly discussed.

Sampling Risk

Sampling involves a degree of risk that the actual samples do not adequately reflect the conditions of the lot. For example, when using the sampling plan recommended in this guide, there are two common risks [see Juran and Gryna (1980) and Juran el. al (1974) for details]:

1. A good seaming practice might be penalized. This is generally referred as the installer's risk and denoted as the risk.
2. A poor seaming practice might go undetected. This is generally referred as an owner/regulators risk and denoted as the risk.

The effects (impacts) of the relative degree of these two risks are summarized in Table B1.

TABLE B1 - THE EFFECTS OF THE RELATIVE DEGREE OF AND RISKS.

Relative	Types of Risks	
Degree	Installers (α) Risk	Owner/Regulators (β) Risk
Low	Loose CQA control; low testing cost	Tight CQA control; high testing cost
High	Tight CQA control; high testing cost	Loose CQA control; low testing cost

Operating Characteristics (OC) Curves

Both of the risks can be quantified by sampling-plan-specific operating characteristics (OC) curves. The OC curve for a sampling plan is a graph that plots the probability that the sampling plan will accept a lot (i.e., the Pa value) versus the percent defective samples in that particular lot. Note that the term "sampling plan" used here corresponds to a batch of "n" destructive testing samples and the criteria for adjusting the sampling interval. Recall Table 2 in the main body of this guide. Figure B1 illustrates the concept of OC curves. In Figure B1, the dashed curve represents an "ideal" OC curve. Here it is desired to accept all lots having less or equal than 2% and reject all lots having greater than 2% failures. In reality, all sampling plans have risks that a "good" lot will be rejected or a "bad" lot will be accepted. This is illustrated by the solid S-shaped curve shown in Figure B1. It is seen that this particular sampling plan will have a 5% risk (100% - 95%) of rejecting a lot having only 1% defects (i.e., a "good" lot) and a 10% risk of accepting a lot having 5% defects (i.e., a "bad" lot).

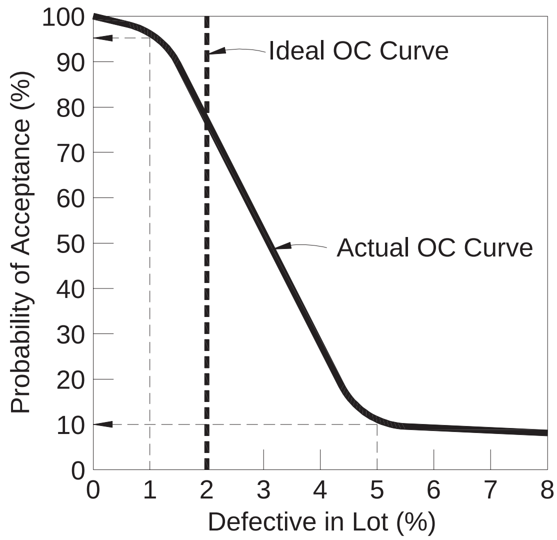


Figure B1 - Ideal and Actual Operating Characteristics Curves for a Sampling Plan

An OC curve can be developed by determining the probability of acceptance for several values of the percent defects. To do so, a statistical distribution of the acceptance probability has to be assumed first. There are three distributions that can be used: hypergeometric, binomial and Poisson distribution. The Poisson distribution is generally preferable due to the ease of calculation. It is used in this guide. The Poisson distribution function to be applied to an acceptance-sampling plan is as follows:

$$P\left(\begin{array}{l}\text{exactly "c" defects}\\ \text{in a batch of size "n"}\end{array}\right) = \frac{e^{-np}(np)^c}{c!} \tag{B1}$$

Most statistics books provide Poisson distribution tables that give the probability of "c" or fewer defects in a batch of size "n" from a lot having a fraction of defect "p".

The Selection of the "I" and "D" Values Listed in Table 2

As mentioned earlier, each of the sampling plans recommended in this guide consists of three variables: the batch size "n", the values of "I" and "D". Note that the values of "I" and "D" are specific values of "c" mentioned in Equation B1. The "I" value corresponds to the judgment criterion of rewarding good seaming practice, i.e., increasing the sampling interval if the number of failed samples does not exceed this particular value. The "D" value, on the other hand, corresponds to the judgment criterion of penalizing poor seaming practice, i.e., decreasing the sampling interval if the number of failed samples equals or exceeds this particular value.

The concept of the OC curves is used to determine the actual values of I's and D's for different sampling plans. The criteria used are as follows:

- For a batch of size "n", the "I" value should yield a 80~90% probability of rewarding good seaming practice, i.e., 80% < Pa < 90%.
- For a batch of size "n", the "D" value should yield a risk of 0.5% or less of penalizing

good seaming practice, i.e., Pa >99.5%. In other words, the probability for good seaming practice to be penalized is extremely small, i.e., less than 0.5%.

The above criteria are subjective. Nevertheless, it is felt to be adequate since the rights of both the installer and the owner/regulator are protected. Recognize that a sampling plan with tighter control (i.e., smaller values of "I" and "D") might seem to be more ideal at first glance, but it may result in a significant increase in the required number of destructive tests, i.e., it may be counter productive.

As an illustration, Figure B2 shows the graphic procedure of obtaining the "I" and "D" values for a batch of 50 samples (n=50) and an anticipated failure percentage of 4%. [In other words, it illustrates the procedure of obtaining one particular pair of numbers listed in Table 2, namely, "I" and "D" equal to 3 and 6, respectively.] Note that each OC curve shown in Figure B2 corresponds to a specific "c" value and is obtained via a Poisson distribution table.

Figure B2 can also used to determine the values of "I" and "D" for sampling plans with the same batch size (i.e., n = 50) but different anticipated failure percentage. The rest of the values listed in Table 2 can be verified in a similar manner using OC curves corresponding to different batch sizes.

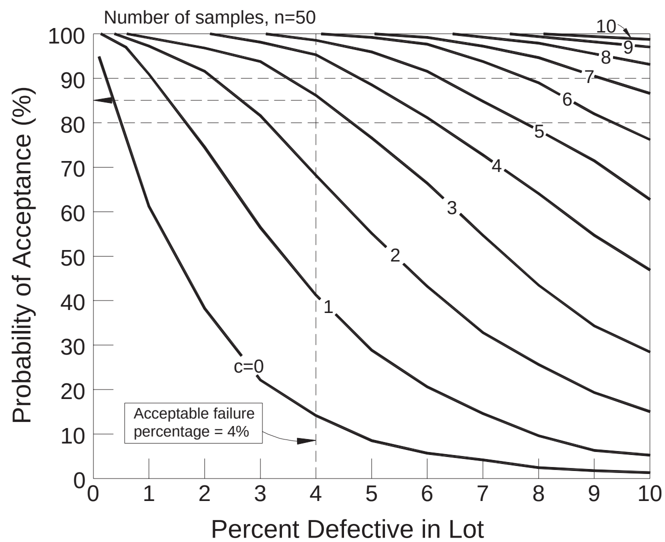


Figure B2 - The Determination of the Values of "I" and "D" for a Batch with 50 Samples and an Anticipated Failure Percentage of 4.0%.

Revision Schedule:

Adopted: March 27,1998

GRI Standard GM17

STANDARD SPECIFICATION FOR TEST PROPERTIES, TESTING FREQUENCY AND RECOMMENDED WARRANTY FOR LINEAR LOW DENSITY POLYETHYLENE (LLDPE) SMOOTH AND TEXTURED GEOMEMBRANES

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers linear low density polyethylene (LLDPE) geomembranes with a formulated sheet density of 0.939 g/ml, or lower, in the thickness range of 0.50 mm (20 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, maximum, or range of physical, mechanical and endurance properties that must be met, or exceeded by the geomembrane being manufactured.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good uniform quality LLDPE geomembranes for use in general applications.

Note 2: Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application. In this situation, interactions with the manufacturers are required.

1.5 This specification also presents a recommended warranty which is focused on the geomembrane material itself.

1.6 The recommended warranty attached to this specification does not cover installation considerations which are independent of the manufacturing of the geomembrane.

Note 3: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

2. Referenced Documents

2.1 ASTM Standards:

D 638	Test Method for Tensile Properties of Plastics
D 792	Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004	Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238	Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505	Test Method for Density of Plastics by the Density-Gradient Technique
D 1603	Test Method for Carbon Black in Olefin Plastics
D 3895	Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218	Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199	Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5323	Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes
D 5994	Test Method for Measuring the Core Thickness of Textured Geomembranes
D 5596	Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5617	Test Method for Multi-Axial Tension Test for Geosynthetics
D 5721	Practice for Air-Oven Aging of Polyolefin Geomembranes GM17 - 3 of 14 rev. 2 - 12/13/00
D 5885	Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry

2.2 GRI Standards:

GM 11	Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device
GM 12	Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pages.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications ref. EPA/600/R-93/182.

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project ref. EPA/600/R-93/182.

Linear Low Density Polyethylene (LLDPE), n - A ethylene/ -olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include hexane, octane, or methyl pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml (ref. Pate, T. J. Chapter 29 in Handbook of Plastic Materials and Technology, I.I. Rubin Ed., Wiley,1990).

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For linear low density polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

4.1 This specification covers linear low density polyethylene geomembranes with a formulated sheet density of 0.939 g/ml, or lower. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.926 g/ml or lower, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min. This refers to the natural, i.e., nonformulated, resin.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be of the same formulation (or other approved formulation) as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth LLDPE geomembranes and Table 2 is for single and double sided textured LLDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is "soft". It is to be understood that the tables refer to the latest revision of the referenced test methods and practices.

Note 4: There are several tests sometimes included in other LLDPE geomembrane specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693 and D 5397)
- Solvent Vapor Transmission
- Water Absorption
- Ozone Resistance
- Hydrostatic Resistance
- Tensile Impact
- Small Scale Burst

- Wide Width Tensile
- Water Vapor Transmission
- Various Toxicity Tests
- Field Seam Strength

Note 5: There are several tests which are included in this standard (that are not customarily required in other LLDPE geomembrane specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet

Note 6: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Tensile Properties, incl. 2% Secant Modulus
- Puncture Resistance
- Axi-Symmetric Break Resistance Strain
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 7: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:

- UV Fluorescent Light Exposure
- Asperity Height Measurement

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The various properties of the LLDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively. Communication and interaction with the manufacturer is strongly suggested.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "minimum average."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

9.2 Marking of the geomembrane rolls shall be done in accordance with the manufacturers accepted procedure as set forth in their quality manual.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

English Units

Table 1(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequenc (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness - mils (min. ave.)	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,00 lb
Tensile Properties *(1)* (min. ave.) • break strength - lb/in. • break elongation - %	D 6693 Type IV	 76 800	 114 800	 152 800	 190 800	 228 800	 304 800	 380 800	 456 800	20,000 lb
2% Modulus – lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulation
Tear Resistance - lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance - lb (min. ave.)	D 4833	28	42	56	70	84	112	140	168	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 1603 *(2)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(4)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 200,000 lb
Oven Aging at 85°C *(5)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 per formulation
UV Resistance *(6)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	 D 3895 D 5885	 N. R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 N.R. *(7)* 35	 per formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(2) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (Metric) Units

Table 1(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm	
Thickness - mm (min. ave.)	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(1)* (min. ave.) • break strength – N/mm • break elongation - %	D 6693 Type IV	13 800	20 800	27 800	33 800	40 800	53 800	66 800	80 800	9,000 kg
2% Modulus – N/mm (max.)	D 5323	210	370	420	520	630	840	1050	1260	per formulation
Tear Resistance - N (min. ave.)	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance - N (min. ave.)	D 4833	120	190	250	310	370	500	620	750	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 1603 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(4)* (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 400	100 400	100 400	100 400	100 400	100 400	100 400	100 400	90,000 kg
Oven Aging at 85°C *(5)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	35 60	35 60	35 60	35 60	35 60	35 60	35 60	35 60	per formulation
UV Resistance *(6)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	D 3895 D 5885	N. R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	N.R. *(7)* 35	per formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(2) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

English Units

Table 2(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) *(1)*	GM 12	10	10	10	10	10	10	10	10	Every 2nd rc *(2)*
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,000 lb
Tensile Properties *(3)* (min. ave.) • break strength – lb/in. • break elongation - %	D 6693 Type IV	30 250	45 250	60 250	75 250	90 250	120 250	150 250	180 250	20,000 lb
2% Modulus – lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulatioi
Tear Resistance – lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance – lb (min. ave.)	D 4833	22	33	44	55	66	88	110	132	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulatioi
Carbon Black Content - %	D 1603 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulatioi
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	 D 3895 D 5885	 N. R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	per formulatioi

(1) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥ 5 mils
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(4) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (Metric) Units

Table 2(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mm (min. ave.) *(1)*	GM 12	10	10	10	10	10	10	10	10	Every 2nd roll *(2)*
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(3)* (min. ave.) • break strength – N/mm • break elongation - %	D 6693 Type IV	5 250	9 250	11 250	13 250	16 250	21 250	26 250	31 250	9,000 kg
2% Modulus – N/mm (max.)	D 5323	210	370	420	520	630	840	1050	1260	per formulation
Tear Resistance – N (min. ave.)	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance – N (min. ave.)	D 4833	100	150	200	250	300	400	500	600	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 1603 *(4)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	 D 3895 D 5885	 N. R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	 N.R. *(9)* 35	per formulation

(1) Of 10 readings; 8 out of 10 must be ≥ 0.18 mm, and lowest individual reading must be ≥ 0.13 mm
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(4) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

11. Warranty

11.1 Upon request of the purchaser in the contract or order, a manufacturer's warranty of the quality of the material shall be furnished at the completion of the terms of the contract.

11.2 A recommended warranty for smooth and textured LLDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.

11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.

Note 9: If a warranty is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

Adoption and Revision Schedule for GRI Test Method GM17

"Test Properties, Testing Frequency and Recommended Warranted for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes"

Adopted: April 3, 2000

Revision 1: June 28, 2000: added a new Section 5.2 that the numeric tables values are neither MARV nor MaxARV. They are to be interpreted per the designated test method. Also, corrected typographical error of textured sheet thickness test method designation from D5199 to D5994.

Revision 2: December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".

Revision 3: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 4.

GRI Test Method GM19*

STANDARD SPECIFICATION FOR SEAM STRENGTH AND RELATED PROPERTIES OF THERMALLY BONDED POLYOLEFIN GEOMEMBRANES

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene (LLDPE) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

Note 2: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

1.4 This specification also suggests the distance between destructive seam samples to be taken in the field, i.e., the sampling interval. However, project-specific conditions will always prevail in this regard.

1.5 This specification is only applicable to laboratory testing.

1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards

D751 Standard Test Methods for Coated Fabrics

D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

2.2 EPA Standards

EPA 600/2.88/052 (NTIS PB-89-129670)

Lining of Waste Containment and Other Containment Facilities

2.3 NSF Standards

NSF International Standard, Flexible Membrane Liners, NSF 54-1993 (depreciated)

2.4 GRI Standards

GM13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GM17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GM18 Test Properties, Testing Frequency and Recommended Warranty for Flexible Polypropylene (fPP and fPP-R) Geomembranes

3. Definition

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

4. Significance and Use

4.1 The various methods of field fabrication of seams in polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel. The specification also provides guidance as to what spacing intervals the samples should be taken at typical field installation projects.

5. Sample and Specimen Preparation

5.1 The spacing for taking field seam samples for destructive testing is to be 1 per 500 feet (1 per 150 m) of seam length, or as by directed by the construction quality assurance inspector. As the project continues and data is accumulated, however, this sampling interval should be varied according to the procedure set forth in GRI GM14. Following this procedure three different situations can result.

5.1.1 Good seaming with fewer rejected test results than the preset historic average can result in a sequential increase in the spacing interval, i.e., one per greater than 500 ft. (one per greater than 150 m).

5.1.2 Poor seaming with more rejected test results than the preset historic average can result in a sequential decrease in the spacing interval, i.e., one per less than 500 ft. (one per less than 150 m).

5.1.3 Average seaming with approximately the same test results as the preset historic average will result in the spacing interval remaining the same, i.e., one per 500 ft. (one per 150 m).

Note 3: The method of attributes referred to in GRI GM14 is only one of several statistical strategies that might be used to vary sampling frequency. The use of control charts should also be considered in this regard.

5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.

5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (as modified by NSF 54) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

6. Assessment of Seam Test Results

6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_o}(100) \tag{1}$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
Lo = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \tag{2}$$

where

S = separation (%)
A = average area of separation, or incursion (in^2 or mm^2)
A0 = original bonding area (in^2 or mm^2)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2 and AD-WLD (unless strength is achieved)

6.2 LLDPE seams – For LLDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Table 2(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) and 2(b).

$$E = \frac{L}{L_O}(100) \tag{1}$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
L_O = original average length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For LLDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) and 2(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) and 2(b). The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_O}(100) \tag{2}$$

where

S = separation (%)
A = average depth of separation, or incursion (in.^{2} or mm^2)
A_O = original bonding distance (in.^{2} or mm^2)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2, AD-WLD (unless strength is achieved)

6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b).

$$E = \frac{L}{L_o}(100) \tag{1}$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
L_o = original gauge length (usually 1.0 in. or 25 mm)

Note 4: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as "not applicable" in Table 3(a) and 3(b).

For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_o}(100) \tag{2}$$

where

S = separation in (%)
A = average depth of separation, or incursion (in.^{2} or mm^2)
A_o = original bonding distance (in.^{2} or mm^2)

Note 5: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%

Extrusion Fillet: AD1, AD2 and AD-WLD (unless strength is achieved)

7. Retest and Rejection

7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

8. Certification

8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

Table 1(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	39	52	65	78	104	130	156
peel separation, %	25	25	25	25	25	25	25

Notes for Tables 1(a) and 1(b):
1. Also for hot air and ultrasonic seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured High Density Polyethylene (HDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]							
shear strength[2], N/25 mm.	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], N/25 mm	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams(1)								
shear strength(2), lb/in.	30	45	60	75	90	120	150	180
shear elongation(3), %	50	50	50	50	50	50	50	50
peel strength(2), lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength(2), lb/in.	30	45	60	75	90	120	150	180
shear elongation(3), %	50	50	50	50	50	50	50	50
peel strength(2), lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

Notes for Tables 2(a) and 2(b):
1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams(1)								
shear strength(2), N/25 mm	131	197	263	328	394	525	657	788
shear elongation(3), %	50	50	50	50	50	50	50	50
peel strength(2), N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength(2), N/25 mm	131	197	263	328	394	525	657	788
shear elongation(3), %	50	50	50	50	50	50	50	50
peel strength(2), N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Reinforced Flexible Polypropylene (fPP) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	30 mil-NR	40 mil-NR	36 mil-R[4]	45 mil-R[4]
Hot Wedge Seams[1]				
shear strength[2], lb/in. (NR); lb (R)	25	30	200	200
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength[2], lb/in. (NR); lb (R)	25	30	200	200
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a

Notes for Tables 3(a) and 3(b):

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongations per D751 for laboratory tested specimens

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Reinforced Flexible Polypropylene (fPP) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.75 mm-NR	1.0 mm-NR	0.91 mm-R[4]	1.14 mm-R[4]
Hot Wedge Seams[1]				
shear strength[2], N/25 mm (NR); N (R)	110	130	890	890
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength[2], N/25 mm (NR); N (R)	110	130	890	890
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a

1.0 Basic Drawing Tools

1.01	**Line**	A straight line from one point to another
1.02	**Pline**	A line that can be modified to have width and/or be joined to other lines or poly-lines.
1.03	**Arc**	A curved line, usually with a starting point, middle point and an end point
1.04	**Circle**	A perfect circle. Can be defined by radius, diameter, two points or three points.
1.05	**Ellipse**	An egg shape, sort of.
1.06	**Polygon**	A shape, such as a triangle, that can be made with as many sides as desired.
1.07	**Donut**	A thick circle defined with an inner diameter and an outer diameter.

2.0 Basic Modification Tools

2.01	**Move**	Command line: move Select objects you want to move, press enter, select a base point, select the point you want to move to.
2.02	**Trim**	Command line: trim Select line or object you want to trim to, hit enter, then trim the lines or objects that are to be trimmed.
2.03	**Extend**	Command line: extend Select line or object you want to extend to, hit enter, then pick the lines you want extended
2.04	**Hatch**	Command line: hatch Pick the hatch you want, look at rotation and scale, associated or not, and then pick how you want to select the area to be hatched. You will need to play with these commands to learn.
2.05	**Explode**	Command line: explode This command is used to separate a block or break up a pline. Select the items you want to explode then hit enter.
2.06	**Stretch**	Command line: stretch This command must be started with a crossing window, window the objects you want to stretch, hit enter, provide a base point then stretch to a new point. It is sometimes helpful to use "snap" setting when using this command.
2.07	**Scale**	Command line: scale Select objects, pick a base point, type in how you want to scale the object. You can also do a reference scaling, Say you have a line in an object that is 6" long and you want it to be 24" long, you input the first dimension and then input the new dimension.
2.08	**Break**	Command break: Select the line you want to break, and then pick the two points you want to open.

2.09 **Break at**

Similar to Break, but you only break at one point.

2.10 **Fillet** Command line: Fillet

Create a fillet by picking two lines. Requires input of the two distances.

2.11 **Radius** Command line: Radius

Creates a radius by picking two lines. Requires inputting a radius. You can radius all corners of a polylines by picking 'polylines' from the side menu.

2.12 **Rotate** Command line: rotate

Pick object to rotate, hit enter, pick a base point, then the angle of rotation.angles are clockwise unless you use a negative, ie.. -90o

2.13 **Mirror** Command Line: mirror

Mirror places an mirror image around a reference line. Pick objects to be mirrored, hit enter, thin pick two points along reference line.

2.14 **Array** Command line: array

Pick objects to array, hit enter, enter number of times you wish to array, then pick the distances between arrays.

2.15 **Polar array** Command line: array p

Same as array but this arrays around a center point. Pick objects, then pick center point, then number of arrays, then the amount of angle, 0 to 360.

3.0 Drawing Commands

3.01 **Offset** Command Line: Offset

Offsets line to a defined distance entered by user.

3.02 **Draw Line w/ Typed Command** Command Line: line

Lines drawn from specific point with typed distance and rotation, ie… @24<45 this draws a line 24" long from a given point at a 45° angle

3.03 **Drawing Lines with Coordinates**
Command Line: line

Lines drawn from two points using given coordinates such are found on customer's drawings. You may enter coordinates in feet or inches. East coordinate goes first. Inches = 10”,10” (enter) 20”,20” always put a comma between east and north

Feet = 10',10' (enter) 20',20'

APPENDIX C
EQUIPMENT BROCHURES

Soil Stabilization and Asphalt Reclamation
8008 Athenour Way
Sunol, CA 94586

EQUIPMENT LIST
Oakland Army Base

Make/Model	Machine No.	Serial No.	Year
MIXERS			
WR 2500	R-23	04.WR.0073	2004
CMI RS 650	R-17	A543-228	1999
COMPACTOR			
REX 355 B	C-13	HNB313	1999
WATER TRUCK			
Kenworth	WT-1	817607	1999
Kenworth	WT-2	790456	1999
Kenworth	WT-3	790457	1999
Kenworth	WT-4	790463	1999
SPEADER			
Custom	S-2	INKCLBOX6PS597861	1993

SPREADER TRUCK SPECIFICATIONS

	LGP Spreader	Off Road	On Road
Frame / Operator's Platform			
Operator's Cab	Yes	Yes	Yes
Heating	Yes	Yes	Yes
Air-Conditioning	Yes	Yes	Yes
Special Coatings / Anti-Oxidation	Yes	Yes	Yes
Frame Size			
Wheel or Track Mounted	Track	Wheel	Wheel
Engine			
Manufacturer	Cummings	Cummings	CAT
Type	Diesel	Diesel	Diesel
Cooling	Water	Water	Water
Engine Speed - RPM	1800	1800	1800
Fuel Consumption - per hour loaded	2	2	2
Control Systems			
Application Controlling Computer	Yes	Yes	Yes
Monitoring Computer	Yes	Yes	Yes
Manual Override	No	No	No
Computer Control of Spread Rates	Automatic	Automatic	Automatic
Type	Ground Radar	Ground Radar	Ground Radar
Brand	Dickey John	Dickey John	Dickey John
4-Wheel Drive	Tracks	Yes	Yes
Fuel / Material Capacity			
Full load tonnage	13	13	13
Weights / Loads			
Surface Loads - Full (Front) PSI	8.5	12.8	23.9
Surface Loads - Empty (Front) PSI	3.7	9	15.8
Shipping Weight - Full (Rear) PSI	6.5	20.5	41.9
Shipping Weight - Empty (Rear) PSI	4	8	21.6
Miscellaneous			
Warning Lights	Yes	Yes	Yes
Working Lights	Yes	Yes	Yes
Horn - reversing horn and rear mirrors	Yes	Yes	Yes
Towing Device	Yes	Yes	Yes
Comprehensive Tool Kit	Yes	Yes	Yes
Compressed Air System	No	Yes	Yes

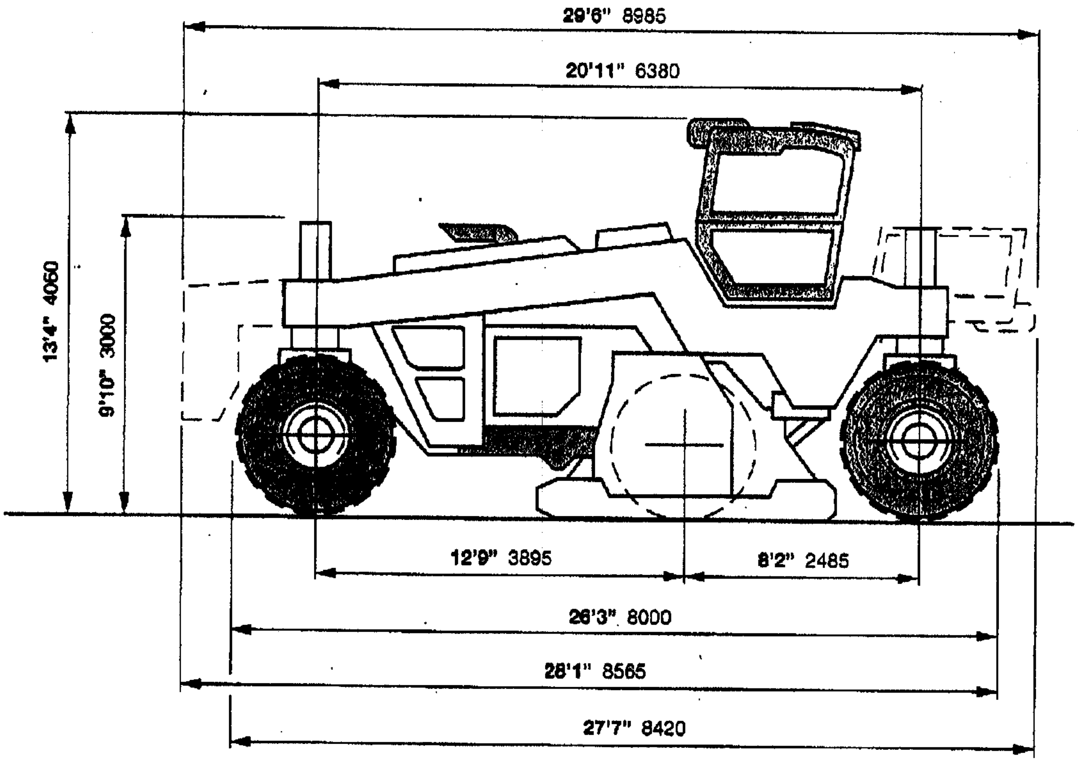
MIXER - WIRTGEN 2500 S

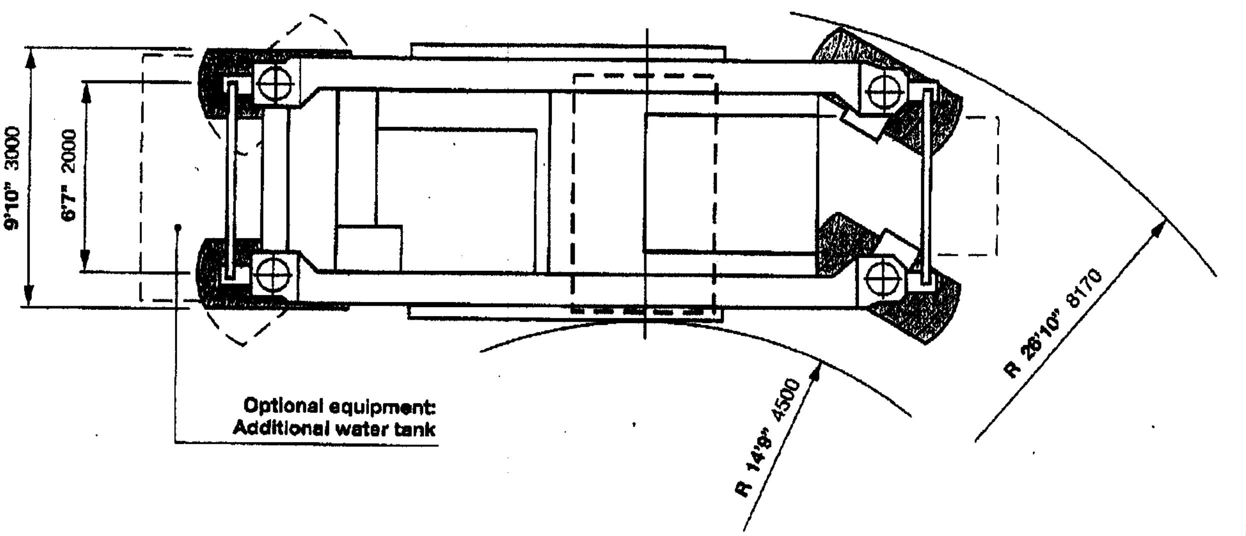
Technical specification

	Recycler WR 2500 S Milling width 8'	Recycler WR 2500 S Milling width 10'
Milling width max.	8' 2,438 mm	10' 3,048 mm
Milling depth *1	0 – 20" 0 – 500 mm	0 – 20" 0 – 500 mm
Milling drum		
Spacing	1¼" 30 mm	1½" 37 mm
Number of tools	224	224
Drum diameter with tools	4' 10" 1,480 mm	4' 10" 1,480 mm
Engine		
Manufacturer	Mercedes-Benz	Mercedes-Benz
Type	OM 444 LA	OM 444 LA
Cooling	Water	Water
No. of cylinders	12	12
Output	500 kW/670 HP/680 PS	500 kW/670 HP/680 PS
Engine speed	2,100 min^{-1}	2,100 min^{-1}
Displacement	1,338 in^3 21,930 cm^3	1,338 in^3 21,930 cm^3
Fuel consumption: 1/1 load	31.7 gal/h 120 l/h	31.7 gal/h 120 l/h
Fuel consumption: 2/3 load	21.1 gal/h 80 l/h	21.1 gal/h 80 l/h
Speed / Gradeability		
1st speed of advance	0 – 50 ft/min 0 – 15 m/min	0 – 50 ft/min 0 – 15 m/min
2nd speed of advance	0 – 131 ft/min 0 – 40 m/min	0 – 131 ft/min 0 – 40 m/min
3rd speed of advance	0 – 262 ft/min 0 – 80 m/min	0 – 262 ft/min 0 – 80 m/min
4th speed of advance	0 – 656 ft/min 0 – 200 m/min	0 – 656 ft/min 0 – 200 m/min
Theor. gradeability, max.	57 %	57 %
Transversal inclination max.	8°	8°
Ground clearance	15" 370 mm	15" 370 mm
Weights / Loads *2		
Front axle load, full tanks	38,581 lbs 17,500 daN (kg)	40,345 lbs 18,300 daN (kg)
Rear axle load, full tanks	34,172 lbs 15,500 daN (kg)	35,274 lbs 16,000 daN (kg)
Shipping weight	69,446 lbs 31,500 daN (kg)	72,312 lbs 32,800 daN (kg)
Operating weight, CE *3	70,548 lbs 32,000 daN (kg)	73,414 lbs 33,300 daN (kg)
Operating weight max.	72,753 lbs 33,000 daN (kg)	75,619 lbs 34,300 daN (kg)
Tyres		
Type of tyres	Diagonal	Diagonal
Tyre size, front / rear	28 L 26	28 L 26
Tank capacities		
Fuel tank	396 gal 1,500 l	396 gal 1,500 l
Hydraulic fluid tank	71 gal 270 l	71 gal 270 l
Water tank	132 gal 500 l	132 gal 500 l
Electrical system	24 V	24 V
Shipping dimensions		
Dimensions of machine (L x W x H)	27'11" x 10'6" x 10'6" 8,500 x 3,200 x 3,200 mm	27'11" x 12'6" x 10'6" 8,500 x 3,800 x 3,200 mm

*1 = The maximum milling depth may deviate from the value indicated, due to tolerances and wear.
*2 = All weights refer to basic machine including operator's cab without any other additional equipment.
*3 = Weight of machine with half-full water tank, half-full fuel tank, driver (75 kg) and tools.

Dimensions in American standard and mm





Machine width for optional equipment "Milling width 10' (3,048 mm)": 12'2" (3,700 mm)

○ Standard ● Optional

Equipment	Recycler WR 2500 S
Frame / operator's platform	
Operator's seat with control consoles, can be turned to any position	○
Operator's cab	●
Heating	●
Air-conditioning	●
Special coating	●
Control system / level control	
Control system with microcontroller	○
CGC (Cockpit Graphic Centre)	○
Printer for job data	●
Ultrasonic sensor for height adjustment	●
Slope sensor for slope adjustment	●
Milling unit	
Quick-change toolholder system HT3 Plus with 20 mm shaft diameter	○
Quick-change toolholder system HT3 Plus with 22 mm shaft diameter	●
Equipment for milling width 10' (3,048 mm) (can only be fitted ex works)	●
Crusher bar	●
Pneumatic cutter ejector	●
Hydraulic drum turning device (for tool changes)	●
Cold recycling system	
Injection system with 1 pump and 1 injection bar	●
Injection system with 1 pump and 2 injection bars	●
Injection system with 2 pumps and 1 injection bar	●
Injection system with 2 pumps and 2 injection bars	●
Injection system for foamed bitumen and water (i.e. 2 pumps and 2 injection bars)	●
Injection bar and feed line (without pump, in combination with WM 1000)	●
Hot bitumen hose for connection to the bitumen tanker, various lengths	●
Additional water tank for producing foamed bitumen, 1,600 l	●
Additional metering system for 1800 l/min water	●
Miscellaneous	
Soundproofing	○
Cyclone air filter	○
Working lights (detachable)	○
Warning lights	○
Horn, reversing horn and rear mirrors	○
Towing device	○
4-wheel steering	○
Loading and lashing lugs	○
Comprehensive tool kit	○
CE mark	○
Safety certificate from the employers' liability insurance association	○
Comprehensive safety package with emergency stop switches	○
Compressed air system	○
High-pressure water wash-down	●
Operation of the recycler with biodegradeable hydraulic fluid	●

WIRTGEN GROUP
WIRTGEN AMERICA

Wirtgen America Inc.
6030 Dana Way
Nashville, TN 37013, USA

Phone: (615) 501-0600
Fax: (615) 501-0691
Internet: www.wirtgenamerica.com

RS-650

CMI MIXER 650

Ground Drive Chrg. Oil Filter. . . 10 micron nominal
In-Tank Suction Strainer with magnets. .200 mesh

WHEEL & PROPEL DRIVE SYSTEMS

Transit Speed– 0-11.3 kph/**0-7 mph**
Working Speed– 0-78 mpm/**0-256 fpm**
In Low Range– 0-39 mpm/**0-128 fpm**
Four-Wheel Drive– High torque integral (motor and reducer) wheel drive units are contained within each wheel to provide the tractive effort required for the toughest jobs, and eliminate axles, transmission drive shaft, and associated maintenance requirements.
Four-Wheel Steering– Provides maximum maneuverability via operator selection of coordinated, crab and either pair of leading wheels as required for working or traveling.
Posi-trac– All four wheel drive units are coordinated to propel the machine without slippage by the use of a unique flow control valve that equalizes flow to all four wheels without spinout in the working mode.
Pump– Infinitely variable electrical displacement control with load sensing and pressure protection systems.
Motors– 2-speed, fixed displacement, closed loop with high pressure limiter.
Tires– Drive, wide base ground grip 28LR26

BI-DIRECTIONAL OPERATION

Dual working directions provide up and down cutting for greater flexibility in gradation and blending control.

Specifications are easier to achieve. Highest possible production is maintained.

LIGHTS

- Head lights 2
- Job site floodlights. 2
- Tail lights 2
- Rotating beacon lights. 2
- Dash lights 3

BRAKES

High-powered–Fail Safe– Hydraulically actuated service brakes in front wheel drive motors. Brakes automatically engage when hydraulic power fails or is shut-off

ELECTRICAL SYSTEM

24 volt, 60 amp charging circuit, battery disconnect.

SERVICE REFILL CAPABILITIES

Primary and secondary fuel filters, rack shut-off solenoid powered through battery disconnect.

	LITERS	U.S. GALLONS
Fuel tank	1,136	**300**
Hydraulic oil tank	189	**50**
Hydraulic reserve tank	19	**5**
Cooling system	180	**48**

Remote radiator fill system for easy access.

OPERATORS CONTROLS

- Modular operator station swivels forward to rearward, and 180° providing excellent visibility of the work area in either direction.
- Machine stability and low vibration reduce operator fatigue.
- Highly-visible systems gauges and controls.
- Micro-processor based control system automatically maintains cutting depth, cross slope, and travel speed. Engine load sensing system automatically adjusts travel speed to cutting conditions maintaining optimum use of engine horsepower.
- A 48 character LCD readout provides a continuous display of cutting depth, travel speed and percent of cross slope.

SPECIFICATIONS

The micro-processor also permits a complete on-line review of all machine operations to assist in operator training and trouble shooting problems in the engine or electrical and hydraulic systems.

- Elevation control is manual or automatic with the right legs tied together permitting automatic control of cross slope.
- Backup manual control system.

STEERING

Four-wheel steering and four-wheel drive lets operator select coordinated steering (all wheels), crab steering, steering of either leading pair of wheels. Its 4,42 m/**14 ft.-6 in.** turning radius and 178 mm/**7 in.** left hand side clearance are the best in the industry.

AIR SYSTEM

Three 26.5 liter/**7 gallon** reservoirs, one engine mounted compressor, approximately 15 SCF (.4 cu m/min.), 110 PSI (10.3 bar) safety valve, quick couplers for hook-up on air impact tool.

OPTIONAL EQUIPMENT

- 1,47 m/**58 in.** diameter cutter mandrel for 508 mm/**20 in.** cutting depth.
- Fully computerized, totally automatic asphalt emulsion additive systems for cold or hot liquids.
- Exclusive Expanded Asphalt Generator and Distribution System.
- Water Spray Systems –
  114-1,135 lpm/**30-300 gpm** with flowmeter.
  227-1,892 lpm/**50-500 gpm** with flowmeter.
- Automatic Cross Slope System.
- Automatic microprocessor control for water distribution system.
- Special application cutter 1,22 m/**48 in.** wide by 1,27 m/**50 in.** diameter; mountings for either left or right side of machine available.
- 1,27 m/**50 in.** diameter cutter x 3.05 m/**10 ft.** wide
- Optional rotor with 23 mm/**7/8 in.** shank tool holder.
- Additional tires or alternate tire sizes optional.
- ROPS 2-part fold down construction for shipping.
- Cab with heater and air conditioner.
- Tow hook attachment–front and rear (weld-on).
- Sizing bar (for 1,27 m/**50 in.** cutter only)
- Hydraulic power-up end slides with independent control for R. H. and L. H. end slides. (standard option)

OPERATING DIMENSIONS

Wheel Base .... 6,50 m/**21 ft.-4 in.**
Wheel Track ..... 2,12 m/**6 ft.-11½ in.**
Turning Radius ...... 4,42 m/**14 ft.-6 in.**
Processing Width ..... 2,46 m/**8 ft.-2 in.**
* Operating Weight.. 29 482.96 kg/**65,000 lb.**
Operating Height–Maximum (with legs extended)
Without ROPS .... 4,28 m/**14 ft.**
With ROPS .... 5,18 m/**17 ft.**

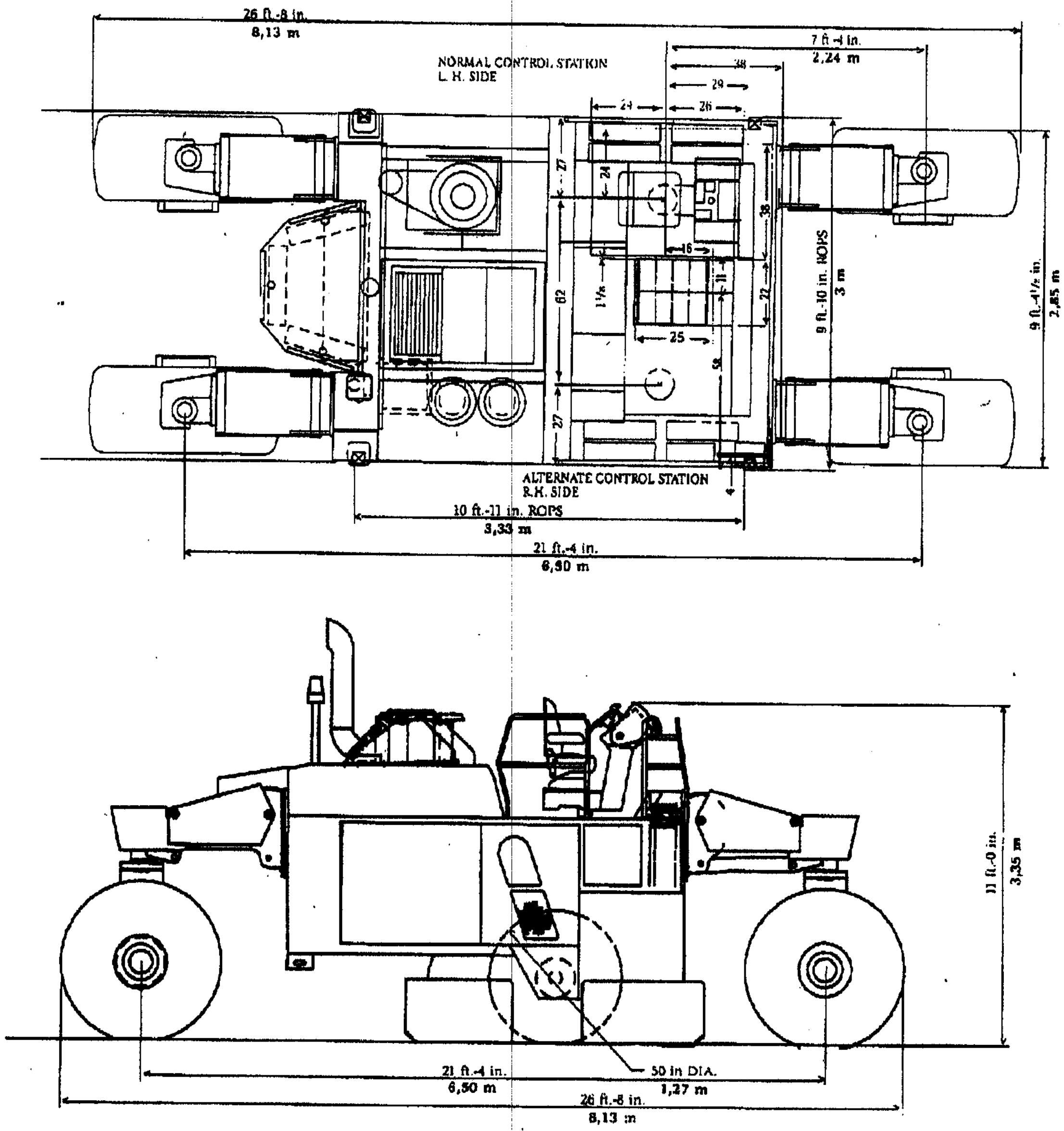
* Dimensions will vary depending on options.

TRANSPORT DIMENSIONS

* Weight approx. .... 29 989 kg/**64,750 lb.**
Width .... 3 m/**9 ft.-10 in.**
Length .... 8,13 m/**26 ft.-8 in.**
Transportation Height–Min.
Without ROPS .... 3,35 m/**11 ft.**
With ROPS Folded... 3,45 m/**11 ft.-4 in.**

* Dimensions will vary depending on options.

SPECIFICATIONS



NOTE: All dimensions and weights provided with standard width cutter. Operating and transportation dimensions and weights will vary depending on selected options.

Material and specifications subject to change without notification.

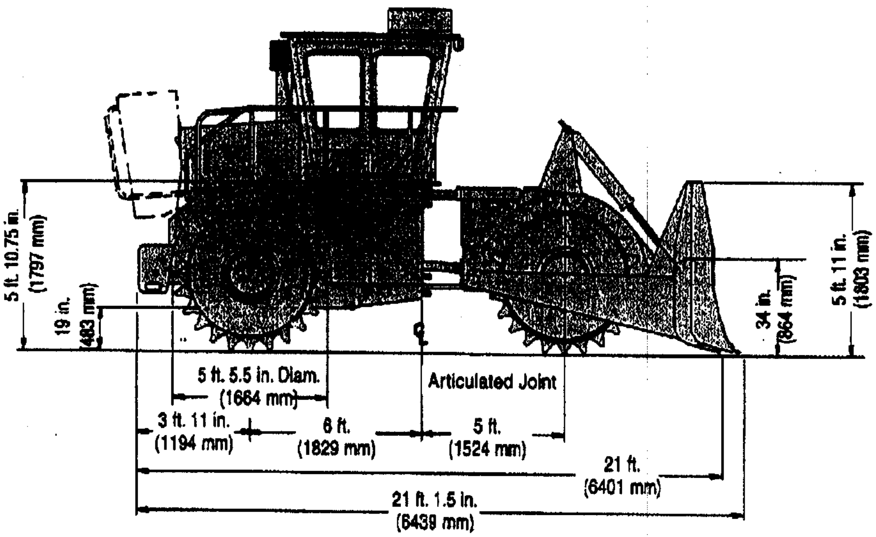
CMI CORPORATION OKLAHOMA CITY, U.S.A.

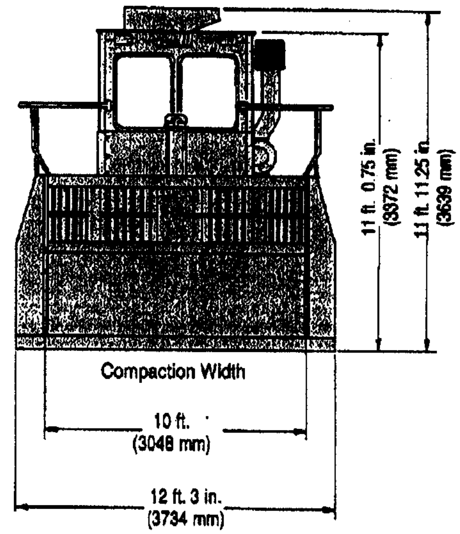
CMI CORPORATION

INTERSTATE-40 AT MORGAN ROAD • P. O. BOX 1985
OKLAHOMA CITY, OK 73101-1985 • U.S.A
PH: 405/787-6020 • FAX: 405/491-2417
WEBSITE: www.cmicorp.com

CMI-5131 (1-97)

Trashmaster 3-35C





Trashmaster

NIXON-EGLI EQUIPMENT CO.

24701 CLAWITER ROAD
HAYWARD, CA 94545
(510) 783-1711

Manufactured exclusively by
CMI Corporation
P O Box 1985
Oklahoma City, OK 73101-1985
Ph: 405/787-6020 Fax: 405/491-2417
Website: www.cmicorp.com

Distributors in principalities throughout the world. Due to ongoing product development programs, CMI reserves the right to amend these specifications at any time without notice.

CMI #6637 (5/98)

odel 3-50 specifications

Rex compactors

FUNCTIONAL

ENGINE: G.M. Diesel 71 Series

TRANSMISSION: Allison CRT 5631

AXLES: Clark 37705 Series front and rear.

DRIVELINES: Mechanics. Heavy duty universals.

DRIVE: 3 wheel configuration for full compaction width and stability. All wheel drive. No-Spin front differential.

STEERING: Articulated, two hydraulic ram actuated.

BRAKES: Clark, Service; Allison, Parking.

LIGHTS: Two front, two rear.

BLADE: Hydraulic up and down, float position.

SHOCK PROTECTION: Rubber shock pads in all wheels isolate shock and vibrational forces from machine. In addition, axle is shock absorber mounted to further protect machine.

OPERATOR'S SEAT: Side facing, adjustable full visibility.

OPERATOR'S CONTROLS: Closely grouped.

OPTIONS

Open ring sheepsfoot wheels — 3½" or 4¼" diameter caps. Consult factory if larger diameter caps are required.

Enclosed operator's cab with 4 windshield wipers, tinted glass, dome light, lockable door.

Heater and defroster.

Air conditioner

Signal horns. Air Electric horn std.

Cold weather starting kit.

Rollover protection structure (consult factory).

TECHNICAL

ENGINE: 8V71 — 318 H.P., 12V starter, 12V batteries, voltage regulator, 52 amp. 12V alternator, variable speed governor, emergency and service shut-offs, 40 g.p.m. (151 Liters per min.) hydraulic pump, 7¼ c.f.m. (3422 cu. cm per sec.) air compressor, 36" blower (914mm) type fan, dry type replaceable air cleaner element with service indicator, fuel and oil filters.

TRANSMISSION AND TORQUE CONVERTER: Matched service, 3 speed forward and reverse, power shift, 0 to 16 m.p.h. speed (24 kph).

GAGES: Ammeter, engine oil pressure, transmission pressure, transmission temperature, air pressure, radiator temperature, hour meter, tachometer and fuel.

BRAKES: Air service; 20 x 5 (508mm x 127mm) on rear axle. Manual parking on transmission.

WHEELS: Open ring, segmented pad, 4" x 6" (102mm x 152mm) pads with raker bars. For sheepsfoot see options.

CAPACITIES: Fuel 110 gal. (416 Liters), hydraulic system 40 gal. (151 Liters), radiator 11 gal. (41.6 Liters), transmission and torque converter 16 gal. (60 Liters), engine crankcase 7 gal. (27 Liters), differentials 52 pts. ea. (25 Liters), wheel ends 25 pts. ea. (12 Liters).

WEIGHT:

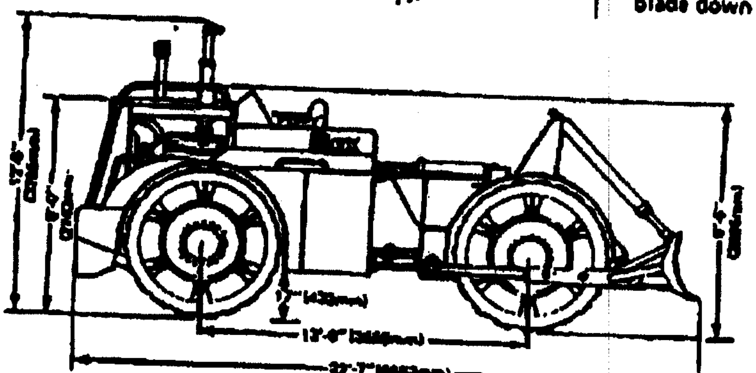
Pactor padded wheels	approx. 24126 KG.
Pactor sheepsfoot wheels,	
3½" (89mm) caps	approx. 24217 KG.
4¼" (108mm) caps	approx. 24489 KG.

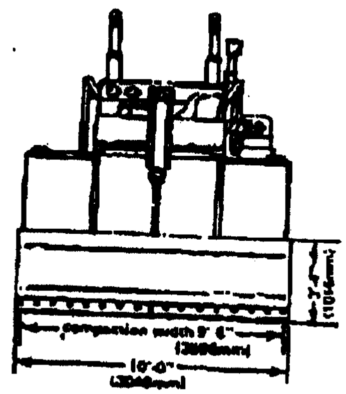
COMPACTIVE STRESSES: — Static

Standard pads	317 p.s.i. (22,28 kgs/cm²)
Optional 3½" dia. sheepsfoot	584 p.s.i. (41,05 kgs/cm²)
Optional 4¼" dia. sheepsfoot	426 p.s.i. (29,94 kgs/cm²)
For larger sheepsfoot	Consult Factory

DIMENSIONS:

Height, travel (less stacks)	9' (2743mm)
Width, travel	10' (3048mm)
Compaction width	9'-6" (2896mm)
Inside turn radius	12'-5" (3785mm)
Outside turn radius	22'-6" (6858mm)
Wheel diameter	
Pactor padded wheel	74" (1880mm)
Pactor sheepsfoot wheel	76" (1930mm)
Blade raise above grade	42" (1067mm)
Blade down below grade	6" (152mm)





NOTE: In accordance with the policy of REXNORD INC. to constantly improve its products, the above specifications are subject to change without notice.

Rexnord

Rexnord Inc.
Construction Machinery Division, Milwaukee, Wisconsin 53201
International Offices: Milwaukee, New York, San Juan, Bogota, Sao Paulo, Caracas, Tokyo, Singapore, Sydney, Johannesburg, Heidelberg.

Cable Address: "REXINTER"

Photo of Spreader

APPENDIX D
MATERIAL SAFETY DATA SHEET (MSDS) FOR PORTLAND CEMENT

Hanson

MATERIAL SAFETY DATA SHEET

Section I - IDENTIFICATION

Product name

PERMANENTE TYPE I-II, III, V, PRONTO, COARSE GRIND, CLASS "G", PREMIUM

MSDS information

This MSDS was produced in January 1998 and replaces any prior versions.

Product code

121, 130, 150, 115, 158, 128, 167

Chemical family

Calcium compounds. Calcium silicate compounds and other calcium compounds containing iron and aluminum make up the majority of this product. Major compounds:

$3CaO \bullet SiO_2$	Tricalcium silicate	$4CaO \bullet Al_2O_3 \bullet Fe_2O_3$	Tetracalcium aluminoferrite
$2CaO \bullet SiO_2$	Dicalcium silicate	$CaSO_4 \bullet 2H_2O$	Calcium sulfate dihydrate or Gypsum
$3CaO \bullet Al_2O_3$	Tricalcium aluminate		

Chemical name and synonyms

Portland cement. Portland cement is also known as hydraulic cement.

Formula

This product consists of finely ground portland cement clinker mixed with a small amount of calcium sulfate dihydrate (gypsum).

Supplier/Manufacturer

HANSON PERMANENTE CEMENT
P.O. BOX 309
PLEASANTON, CA 94566
(925) 846-8800

Emergency contact information

KEN FIDLER
(408) 996-4226

Section 2 - COMPONENTS

Hazardous Ingredients

Portland cement (CAS# 65997-15-1) - approximately 95% by weight
ACGIH TLV-TWA (1995-1996) = 10 mg total dust/m^3
OSHA PEL (8-hour TWA) = 50 million particles/ft^3

Gypsum (CAS# 7778-18-9) - approximately 5% by weight
ACGIH TLV-TWA (1995-1996) = 10 mg total dust/m^3
OSHA PEL (8-hour TWA) = 10 mg total dust/m^3
OSHA PEL (8-hour TWA) = 5 mg respirable dust/m^3

Quartz (CAS# 14808-60-7) - less than 0. 1 % by weight
ACGIH TLV-TWA (1995-1996) = 0.10 mg respirable quartz dust/m^3
OSHA PEL (8-hour TWA) = (10 mg of respirable dust/m^3) / (percent silica + 2)
NIOSH REL (8-hour TWA) = 0.05 mg respirable quartz dust/m^3

Trace Elements

Portland cement is made from materials mined from the earth and is processed using energy provided by fuels. Trace amounts of naturally occurring, potentially harmful chemicals might be detected during chemical analysis. For example, Hanson Permanente portland cement may contain up to 0.75% insoluble residue, some of which may be free crystalline silica. Other trace constituents may include calcium oxide (also known as free lime or quick lime), free magnesium oxide, potassium and sodium sulfate compounds, chromium compounds, and nickel compounds.

Section 3 - HAZARDS IDENTIFICATION

Emergency Overview

Portland cement is a light gray powder that poses little immediate hazard. A single short term exposure to the dry powder is not likely to cause serious harm. However, exposure of sufficient duration to wet portland cement can cause serious, potentially irreversible tissue (skin or eye) destruction in the form of chemical (caustic) burns, including third degree burns. The same type of tissue destruction can occur if wet or moist areas of the body are exposed for sufficient duration to dry portland cement.

Potential Health Effects

- **Relevant Routes of Exposure:**
  Eye contact, skin contact, inhalation, and ingestion.
- **Effects resulting from eye contact:**
  Exposure to airborne dust may cause immediate or delayed irritation or inflammation.

  Eye contact by larger amounts of dry powder or splashes of wet portland cement may cause effects ranging from moderate eye irritation to chemical burns and blindness. Such exposures require immediate first aid (see Section 4) and medical attention to prevent significant damage to the eye.

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- **Effects resulting from skin contact:**
  Discomfort or pain cannot be relied upon to alert a person to a hazardous skin exposure.
  Consequently, the only effective means of avoiding skin injury or illness involves minimizing skin contact, particularly contact with wet cement. Exposed persons may not feel discomfort until hours after the exposure has ended and significant injury has occurred.

  Exposure to dry portland cement may cause drying of the skin with consequent mild irritation or more significant effects attributable to aggravation of other conditions. Dry portland cement contacting wet skin or exposure to moist or wet portland cement may cause more severe skin effects including thickening, cracking or fissuring of the skin. Prolonged exposure can cause severe skin damage in the form of (caustic) chemical burns.

  Some individuals may exhibit an allergic response upon exposure to portland cement, possibly due to trace amounts of chromium. The response may appear in a variety of forms ranging from a mild rash to severe skin ulcers. Persons already sensitized may react to their first contact with the product. Other persons may first experience this effect after years of contact with portland cement products.
- **Effects resulting from inhalation:**
  Portland cement may contain trace amounts of free crystalline silica. Prolonged exposure to respirable free crystalline silica may aggravate other lung conditions. It also may cause delayed lung injury including silicosis, a disabling and potentially fatal lung disease, and/or other diseases. (Also see "Carcinogenic potential" below.)

  Exposure to portland cement may cause irritation to the moist mucous membranes of the nose, throat, and upper respiratory system. It may also leave unpleasant deposits in the nose.
- **Effects resulting from ingestion:**
  Although small quantities of dust are not known to be harmful, ill effects are possible if larger quantities are consumed. Portland cement should not be eaten.
- **Carcinogenic potential:**
  Portland cement is not listed as a carcinogen by NTP, OSHA, or IARC. It may, however, contain trace amounts of substances listed as carcinogens by these organizations.

  Crystalline silica, a potential trace level contaminant in portland cement, is now classified by IARC as a known human carcinogen (Group 1). NTP has characterized respirable silica as "reasonably anticipated to be [a] carcinogen".
- **Medical conditions which may be aggravated by inhalation or dermal exposure:**
  - Pre-existing upper respiratory and lung diseases.
  - Unusual (hyper) sensitivity to hexavalent chromium (chromium^{+6}) salts.

Section 4 - FIRST AID

Eyes

Immediately flush eyes thoroughly with water. Continue flushing eye for at least 15 minutes, including under lids, to remove all particles. Call physician immediately.

Skin

Wash skin with cool water and pH-neutral soap or a mild detergent intended for use on skin. Seek medical treatment in all cases of prolonged exposure to wet cement, cement mixtures, liquids from fresh cement products, or prolonged wet skin exposure to dry cement.

Inhalation of Airborne Dust

Remove to fresh air. Seek medical help if coughing and other symptoms do not subside. ("Inhalation" of gross amounts of portland cement requires immediate medical attention.)

Ingestion

Do not induce vomiting. If conscious, have the victim drink plenty of water and call a physician immediately.

Section 5 - FIRE & EXPLOSION DATA

Flash point....NA
Lower Explosive Limit....NA
Upper Explosive Limit....NA
Auto ignition temperature....Non combustible
Extinguishing media....Non combustible
Special fire fighting procedures....None. (Although portland cement poses no fire-related hazards, a self-contained breathing apparatus is recommended to limit exposure to combustion products when fighting any fire.)

Hazardous combustion products....None
Unusual fire and explosion hazards....None

Section 6 - ACCIDENTAL RELEASE MEASURES

Collect dry material using a scoop. Avoid actions that cause dust to become airborne. Avoid inhalation of dust and contact with skin. Wear appropriate personal protective equipment as described in Section 8.

Scrape up wet material and place in an appropriate container. Allow the material to "dry" before disposal. Do not attempt to wash portland cement down drains.

Dispose of waste material according to local, state and federal regulations.

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Section 7 - HANDLING AND STORAGE

Keep portland cement dry until used. Normal temperatures and pressures do not affect the material.

Promptly remove dusty clothing or clothing which is wet with cement fluids and launder before reuse. Wash thoroughly after exposure to dust or wet cement mixtures or fluids.

Section 8 - EXPOSURE CONTROLS/PERSONAL PROTECTION

Skin protection

Prevention is essential to avoiding potentially severe skin injury. Avoid contact with unhardened (wet) portland cement products. If contact occurs, promptly wash affected area with soap and water. Where prolonged exposure to unhardened portland cement products might occur, wear impervious clothing and gloves to eliminate skin contact. Where required, wear boots that are impervious to water to eliminate foot and ankle exposure.

Do not rely on barrier creams; barrier creams should not be used in place of gloves.

Periodically wash areas contacted by dry portland cement or by wet cement or concrete fluids with a pH neutral soap. Wash again at the end of the work. If irritation occurs, immediately wash the affected area and seek treatment. If clothing becomes saturated with wet concrete, it should be removed and replaced with clean dry clothing.

Respiratory Protection

Avoid actions that cause dust to become airborne. Use local or general ventilation to control exposures below applicable exposure limits.

Use NIOSH/MSHA-approved (under 30 CFR 1 1) or NIOSH-approved (under 42 CFR 84) respirators in poorly ventilated areas, if an applicable exposure limit is exceeded, or when dust causes discomfort or irritation.
(Advisory: Respirators and filters purchased after July 10, 1998, must be certified under 42 CFR 84.)

Ventilation

Use local exhaust or general dilution ventilation to control exposure within applicable limits.

Eye protection

When engaged in activities where cement dust or wet cement or concrete could contact the eye, wear safety glasses with side shields or goggles. In extremely dusty environments and unpredictable environments, wear unvented or indirectly vented goggles to avoid eye irritation or injury. Contact lenses should not be worn when working with portland cement or fresh cement products.

Section 9 - PHYSICAL AND CHEMICAL PROPERTIES

Appearance....Gray powder
Odor....No distinct odor
Physical state....Solid (powder)
pH (in water) (ASTM D 1293-95)....12 to 13
Solubility in water....Slightly soluble (0.1 to 1.0%)
Vapor pressure....NA

Vapor density....NA
Boiling point....NA (i.e., >1000C)
Melting point....NA
Specific gravity (H_20 = 1.0)....3.15
Evaporation rate....NA

Section 10 - STABILITY AND REACTIVITY

Stability

Stable.

Conditions to avoid

Unintentional contact with water.

Incompatibility

Wet portland cement is alkaline. As such it is incompatible with acids, ammonium salts and aluminum metal.

Hazardous decomposition

Will not spontaneously occur. Adding water results in hydration and produces (caustic) calcium hydroxide.

Hazardous polymerization

Will not occur.

Section 11 - TOXICOLOGICAL INFORMATION

For a description of available, more detailed toxicological information, contact the supplier or manufacturer.

Section 12 - ECOLOGICAL INFORMATION

Ecotoxicity

No recognized unusual toxicity to plants or animals

Relevant physical and chemical properties

(See Sections 9 and 1 0.)

Section 13 - DISPOSAL

Dispose of waste material according to local, state and federal regulations. (Since portland cement is stable, uncontaminated material may be saved for future use.)

Dispose of bags in an approved landfill or incinerator.

Section 14 - TRANSPORTATION DATA

Hazardous materials description/proper shipping name

Hanson

Portland cement is not hazardous under U.S. Department of Transportation (DOT) regulations.

Hazard Class Not Applicable

Identification Number .... Not Applicable

Required label text .... Not Applicable

Hazardous substances/reportable quantities (RQ) .... Not Applicable

Section 15 - OTHER REGULATORY INFORMATION

Status under USDOL-OSHA Hazard Communication Rule, 29 CFR 1910.1200

Portland cement is considered a "hazardous chemical" under this regulation, and should be part of any hazard communication program.

Status under CERCLA/Superfund, 40 CFR 117 and 302

Not listed.

Hazard Category under SARA (Title 111), Sections 311 and 312

Portland cement qualifies as a "hazardous substance" with delayed health effects.

Status under SARA (Title 1 1 1), Section 313

Not subject to reporting requirements under Section 313.

Status under TSCA (as of May 1997)

Some substances in portland cement are on the TSCA inventory list.

Status under the Federal Hazardous Substances Act

Portland cement is a "hazardous substance" subject to statutes promulgated under the subject act.

Status under California Proposition 65

This product contains chemicals (trace metals) known to the State of California to cause cancer, birth defects or other reproductive harm. California law requires the manufacturer to give the above warning in the absence of definitive testing to prove that the defined risks do not exist.

Status under Canadian Environmental Protection Act

Not listed.

Status under WHMIS

Portland cement is considered to be a hazardous material under the Hazardous Products Act as defined by the Controlled Products Regulations (Class E - Corrosive Material) and is therefore subject to the labeling and MSDS requirements of the Workplace Hazardous Materials Information System (WHMIS).

Section 16 - OTHER INFORMATION

Prepared by

Bruce Carter, Manager of Technical Services

Approved by

Earl Bouse, Vice President, Manufacturing Services

Approval date or Revision date

January 1, 1998

Date of previous MSDS

June 6, 1991

MSDS number

1998-1

Other important information

Portland cement should only be used by knowledgeable persons. A key to using the product safely requires the user to recognize that portland cement chemically reacts with water, and that some of the intermediate products of this reaction (that is, those present while a portland cement product is "setting") pose a far more severe hazard than does portland cement itself

While the information provided in this material safety data sheet is believed to provide a useful summary of the hazards of portland cement as it is commonly used, the sheet cannot anticipate and provide the all of the information that might be needed in every situation. Inexperienced product users should obtain proper training before using this product.

In particular, the data furnished in this sheet do not address hazards that may be posed by other materials mixed with portland cement to produce portland cement products. User's should review other relevant material safety data sheets before working with this portland cement or working on portland cement products, for example, portland cement concrete.

APPENDIX E

NOTIFICATION OF DECISION TO APPROVE A SITE-SPECIFIC TREATMENT VARIANCE FROM LAND DISPOSAL RESTRICTION TREATMENT STANDARDS FOR HAZARDOUS WASTES 40 CFR § 268.44 (H)

AMENDMENT 1 SITE-SPECIFIC TREATMENT VARIANCE FROM LAND DISPOSAL RESTRICTION TREATMENT STANDARDS FOR HAZARDOUS WASTES 40 CFR § 268.44 (H)

COPY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

RECEIVED
OCT 01 2002
?LER & KALINOWSKI, INC.

September 27, 2002

Mr. Roger Caswell
BRAC Environmental Coordinator
Department of the Army
Military Traffic Management Command
2475D W. 12th Street
Oakland Army Base
Oakland, CA 94607-5000

OPTIONAL FORM 99 (7-90) FAX TRANSMITTAL	# of pages ► 15
To Andy Stafford	From Jim Sullivan
Dept./Agency	Phone #
Fax # 650 552 2912	Fax #
NSN 7540-01-317-7368 5099-101	GENERAL SERVICES ADMINISTRATION

Re: Decision to Approve Site-specific LDR Treatment Variance Under 40 CFR § 268.44 (h)

Dear Mr. Caswell:

Enclosed you will find a signed copy of the Decision Document which responds to your July 15, 2002, "Petition for Site-specific LDR Treatment Variance under 40 CFR § 268.44 (h) for Remediation Waste at Former Oil Reclaiming Plant/Building 1 Area, Oakland, California." The Decision Document approves your Petition, with certain added conditions.

We look forward to working with the Army and other project participants upon completion of the upcoming Treatability Studies. In the interim, if you have any questions regarding this matter, you may contact Mr. Jim Sullivan of my staff at (415) 972-3309.

Sincerely,

Jeff Scott

Jeff Scott, Director
Waste Management Division

Enclosure

cc: Aliza Gallo (w/ enc.)
Executive Director
Oakland Base Reuse Authority
700 Murmansk Street, Suite 3
Oakland, California 94607

NOTIFICATION OF DECISION TO APPROVE A SITE-SPECIFIC TREATMENT VARIANCE FROM LAND DISPOSAL RESTRICTION TREATMENT STANDARDS FOR HAZARDOUS WASTES 40 CFR § 268.44 (h)

Petitioner:	Department of the Army
Facility:	Oakland Army Base
Facility Location:	Building 1, between Alaska and Bataan Streets at Maritime Street on the former Oakland Army Base, Oakland, California.
Petitioner Representative:	Mr. Roger Caswell
Title:	BRAC Environmental Coordinator Department of the Army Military Traffic Management Command 2475D W. 12th Street Oakland Army Base Oakland, CA 94607-5000
Phone:	(510) 466-2058
EPA Contact:	Jim Sullivan
Title:	Environmental Engineer
Phone:	(415) 972-3309
Date of Petition:	July 15, 2002

Subject of the Petition: Building 1 Remediation Wastes, which consist of soil inseparably commingled with tarry residue generated by a former waste oil reclaiming plant which operated at the Oakland Army Base ("OARB") from the 1920s until 1941. The estimated inventory of Building 1 Remediation Wastes subject to this petition is 6,000 cubic yards.

Summary of the Petition: The Building 1 Remediation Wastes, which are the subject of this Petition, are expected to display the D008 toxicity characteristic for lead and/or the D002 corrosivity characteristic. The Petitioner also believes that the Building 1 Remediation Wastes will also contain polycyclic aromatic hydrocarbons ("PAHs"), polychlorinated dibenzodioxins ("PCDDs"), polychlorinated dibenzofurans ("PCDFs"), and polychlorinated biphenyls ("PCBs"), which constitute underlying hazardous constituents ("UHCs") under the RCRA Land Disposal Restrictions ("LDR") program. The Petitioner seeks a one-time, site-specific variance from various alternative LDR treatment standards for soil, pursuant to 40 C.F.R. § 268.44(h).

Public Review: The complete petition was maintained at the following repositories:

volume". See 40 C.F.R. § 268.2 (k).

Under 40 C.F.R. § 268.49(c)(1)(B), for D008 Building 1 Remediation Wastes before they were placed in an off-site RCRA hazardous waste management facility, the Petitioner would be required to achieve 90 percent reduction in lead content, unless the lead concentration is less than 10 times the Universal Treatment Standards ("UTS") for lead of 0.75 mg/L as measured in the extract of the Toxicity Characteristic Leaching Procedure ("TCLP"), or 7.5 mg/L TCLP lead. The Petitioner anticipates that under the remedy proposed in the Remedial Action Plan, solidification/stabilization, it can not be certain that this standard would be met for all of the Building 1 Remediation Wastes without exception. The oil content of the Building 1 Remediation Waste could interfere with the bonds between waste particles and added binders, thereby adversely impacting the effectiveness of the solidification/stabilization. Therefore, the Petitioner has sought a variance from the alternative soil treatment standard for lead.

Under 40 C.F.R. § 268.49(c)(1)(A), the Petitioner would be required to achieve a 90 percent reduction in PAH, PCDD, PCDF, and PCB content, unless the individual concentrations of these constituents in the Building 1 Remediation Wastes are less than a concentration 10 times the UTSs for these UHCs, before they were placed in an off-site RCRA permitted hazardous waste landfill. As shown in Table 1 (see, attached), samples of the tarry residue portion of the Remedial Wastes taken in 2000 and 2001 exhibited concentrations of PAHs ranging from 16 milligrams per kilogram ("mg/kg") for anthracene to 1,200 mg/kg of naphthalene. The UTS for these constituents are 3.4 and 5.6 mg/kg, respectively. Total tetrachlorinated dibenzofurans ("TCDFs") and total pentachlorinated dibenzofurans ("PeCDFs") were detected at 0.128 and 0.0968 mg/kg, respectively, in the tarry residue sample collected in 2000. TCDFs and PeCDFs are types of PCDFs or dioxin-like compounds. The UTS is 0.001 mg/kg for either TCDFs or PeCDFs. PCBs were detected at 13 mg/kg in the sample taken in 2000. The UTS for PCBs is 10 mg/kg. The Petitioner anticipates that under the remedy proposed in the Remedial Action Plan, solidification/ stabilization, it can not be certain that this standard would be met for the whole of the Building 1 Remediation Wastes without exception. Although literature pertaining to the effectiveness of solidification/stabilization indicates that the technology is effective for nonhalogenated semivolatiles (e.g., PAHs), the technology is considered only potentially effective for PCDDs, PCDFs, and PCBs.

Therefore, the Petitioner has sought a variance from the UTSs for PCDDs, PCDFs, PCBs and PAHs. Although the solidification/stabilization technology may achieve compliance with the alternative treatment standards for PAHs in soil, the variance for PAHs is sought because of the unique characteristics of the Building 1 Remediation Wastes and the potential effect that these characteristics may have on the ability of solidification/stabilization to treat PAHs.

Under 40 C.F.R. § 268.49(c)(2), if the Building 1 Remediation Wastes demonstrate the D002 corrosivity characteristic, they must be treated to eliminate that characteristic. The Petitioner anticipates that under the remedy proposed in the Remedial Action Plan, solidification/ stabilization, all D002 characteristic Building 1 Remediation Wastes will be treated to neutralize the pH of these wastes, and that the D002 treatment standard will be met for all corrosive characteristic Building 1 Remediation Wastes. Accordingly, a site-specific variance from 40

The selected percent reduction of leachable lead for the Building 1 Remediation Wastes will be based on the lowest percent reduction of leachable lead observed as a result of the most effective solidification/stabilization technology tested, a factor of safety intended to account for the inevitable variability encountered during remedial work and implementability. This selected percent reduction for leachable lead will be placed in an addendum to the final OARB LDR variance decision document and will represent the final treatment standard for the Building 1 Remediation Waste under this variance.

3. Authority Of The Director Of The Waste Management Division Of EPA Region IX To Approve Or Deny The Petition For A Variance Pursuant To 40 C.F.R. 268.44(h)

The determination of the petition by the Director of the Waste Management Division of EPA, Region IX, (the Region) is in accordance with delegations 8-45-A and 8-45-B (March 24, 1997) which delegate to the Regional Administrators the authority to approve or deny applications submitted pursuant to 40 C.F.R. 268.44(h) for site-specific treatment variances from LDR treatment standards, and with delegations R9 1280.18 and R9 1280.19 (March 28, 1998) which further delegate the authority from the Regional Administrator to the Director of the Waste Management Division.

4. Site Background

Prior to the Army acquiring the site, a waste oil reclaiming plant was operated in the area of the OARB that now contains Building 1. The former oil reclaiming plant likely operated from approximately the mid- to late-1920s to 1941. The former oil reclaiming plant generated acid clay sludge as a by-product, and apparently disposed of this "tarry residue" in the Building 1 area during at least some of the period the former oil reclaiming plant operated.

The Army acquired the site in 1941 for the OARB, and the former oil reclaiming plant operations ceased in that year. The Army began covering the tarry residue in 1941 with approximately three feet of soil to allow construction of Building 1, which served as Army headquarters for the OARB until Congressional closure of the in 1995 and cessation of military activities in 1999.

The Amended Draft Final Reuse Plan for the Oakland Army Base, July 23, 2001 ("Amended Reuse Plan") designates the Oakland Base Reuse Authority ("OBRA") as the Local Reuse Authority designated to accept the majority of the OARB from the Army. The Amended Reuse Plan envisions that OBRA will transfer portions of the land, including the former oil reclaiming plant/Building 1 area, to the City of Oakland Redevelopment Agency ("ORA"), which will manage this property on behalf of the City of Oakland. The Amended Reuse Plan describes commercial/ industrial redevelopment for the Building 1 area.

particles as classified by the U.S. Natural Resources Conservation Service, or a mixture of such materials with liquids, sludges or solids which is inseparable by simple mechanical removal processes and is made up primarily of soil by volume based on visual inspection. Any deliberate mixing of prohibited hazardous waste with soil that changes its treatment classification (i.e. from waste to contaminated soil) is not allowed under the dilution prohibition in 40 C.F.R. § 268.3.

Therefore, as contaminated soil, that portion of the Building 1 Remediation Wastes displaying the D002 and/or D008 hazardous characteristic must meet the 40 C.F.R. § 268.49 alternative LDR treatment standards for contaminated soil.

The estimated inventory of Building 1 Remediation Wastes subject to this petition is 6,000 cubic yards.

6. Description Of Facility Proposed For Waste Disposal After Treatment

The Petitioner proposes to treat the soil by solidification/stabilization at the OARB. The treatment will convert the Building 1 Remediation Wastes to a less soluble and mobile form, prior to its shipment for offsite disposal in a RCRA Subtitle C hazardous waste disposal facility. The disposal facility where the waste is anticipated to be disposed of is Chemical Waste Management's Kettleman Hills facility. The Kettleman Hills facility is a fully permitted, double-lined landfill with a leachate collection system and a groundwater monitoring system. In the unlikely event that a landfill liner system was to fail, any releases from the landfill to groundwater would be detected and addressed by the groundwater monitoring system. Additionally, the location of the Kettleman Hills facility is such that environmental receptors are not readily available. The surrounding area has a small local population, a deep water table and an arid climate (e.g., little rainfall).

Under these circumstances, the disposal of the Building 1 Remediation Wastes in a double-lined landfill, with additional levels of protection in place for the monitoring and control of landfill leachate and groundwater, presents no realistic potential for potable groundwater to be impacted by the Building 1 Remediation Wastes and no realistic potential of chronic human exposure to this waste.

7. Regulatory Authority And Other References

The requirements for obtaining a site-specific treatment variance are set forth at 40 C.F.R. § 268.44(h). Relevant parts of these requirements providing justification for a site-specific treatment variance are as follows:

(h) Based on a petition filed by a generator or treater of hazardous waste, the Administrator or his or her delegated representative may approve a site-specific variance cancer risk to human receptors under a commercial/industrial exposure scenario of 7 x 10E-4 and the corresponding value of the non-cancer Health Index is 10. Under the unlikely event of a residential exposure scenario, the chronic and acute risk associated with exposure to those materials poses a potential cancer risk to human receptors of 5 x 10E-3 and the corresponding value of the non-cancer Health Index is 37. There also exists a small possibility that the off-gases from those materials beneath Building 1 could exceed the lower explosive limit in a confined space, thus adding to the risk posed by the waste in-place. Therefore a remedial option for the Building 1 Remediation Wastes is preferred.

As the Remediation of the OARB is being conducted in accordance with Chapter 6.8 of the California Health and Safety Code, the Petitioner has the legal option of leaving the Building 1 Remediation Wastes onsite. Section 25356.1(d) allows for the consideration of six factors in determining the remedy to be used to achieve final cleanup. In the case of the OARB, none of these factors compel the Petitioner to excavate the Building 1 Remediation Wastes. With engineering controls (e.g., perimeter sheeting, a multi-layer cap and groundwater monitoring) and restrictive land use covenants, the Building 1 Remediation Wastes could remain unexcavated. The major practical drawback of this non-removal remedy is that its selection would rule out most future beneficial land reuse scenarios.

Based on the calculated risk stated above and in accordance with the Remedial Action Plan for the OARB, the Petitioner's intention is to remove the source of the contamination in the vicinity of Building 1. The Petitioner has indicated that it believes the only way to achieve the applicable alternative LDR standards for contaminated soil without the relief sought in this variance is via the use of combustion technology for the organic Hazardous Air Pollutant ("HAP"), including PAHs, dioxins, and furans. The application of such technology, while technically possible, remains unsuitable and impractical from a technical standpoint, and indeed, technically inappropriate (within the variance criteria in section 268.44 (a) (2)) as well due to the very high concentration of lead.[2] Cf. Section 268.3 (c), stating that combustion of certain high metal content wastes is prohibited; although the wastes that are the subject of this petition do not fall directly under this prohibition due to their organic content (see section 268.3 (c) (1)), nonetheless this provision supports the principle that it can be inappropriate to use combustion technology to treat wastes with high HAP metal concentrations. Shipping the material to an off-site commercial incinerator also would likely not be possible due to the high lead content and the presence of low levels of dioxin and PCBs. Additionally, siting an on-site thermal unit within the densely populated City of Oakland would be difficult, if not impossible, and more likely to cause net environmental detriment through the transfer of a semi-volatile metal, lead, and some amount of incompletely combusted organic constituents, from their current stable matrix (e.g., tarry soil) to the air. The technical

[2] Lead as high as 100,000 mg/kg in acid clay sludge has been reported in the literature. The maximum concentration of lead detected in tarry residue collected from the OARB is 11,800 mg/kg.

EPA views this result as environmentally preferable to other remedial options that could legally be pursued at OARB (i.e., leaving the soil in place).[3] EPA believes the benefits of assured soil removal followed by substantial treatment and secure disposal in an off-site RCRA Subtitle C hazardous waste disposal facility as proposed by the Petitioner is superior to applying the treatment standard as specified by 40 C.F.R. § 268.49. Application of the treatment standard could possibly result in Building 1 Remediation Wastes remaining at the site and being left untreated. Consequently, EPA is finding that requiring treatment based on the performance of BDAT is not appropriate because, in the specific circumstance of the OARB, it would most likely result in a net environmental detriment. See generally LEAN, 172 F. 3d at 69-70 (upholding EPA's "environmentally inappropriate" treatment variance as reasonable due to the very problem presented here: insistence on the strictest treatment standards can lead to a net environmental detriment in remediation situations because of the possibility in many instances that there is a choice to simply leave the waste in place without any treatment at all; partial treatment and secure disposal thus can be said to minimize threats posed by waste disposal when compared to the option of capping remediation wastes in place).

EPA is also finding that under the circumstances presented here, threats posed by land disposal of the soil including current and potential threats posed by the soil remaining at the site, are minimized (within the meaning of Sec. 3004(m)) by the combination of removal of the soil followed by substantial treatment (stabilization of the lead) and secure disposal in an off-site RCRA Subtitle C hazardous waste disposal facility. LEAN, 172 F. 3d at 69-70 (allowing comparison of disposal environment where a Remediation waste may be left in place with disposal conditions at a site to which the waste may be excavated and disposed (after treatment) in evaluating whether threats posed by land disposal of the waste have been minimized).

For the reasons set forth above, the Region has determined that approval of the proposed treatment variance will allow the Petitioner to dispose of the Building 1 Remediation Wastes in an environmentally protective manner, while avoiding treatment which is environmentally inappropriate (and likely technically inappropriate as well) because it could lead to the result of less secure disposal conditions and no treatment (and also could lead to the technically inappropriate combustion of soils with high metal concentrations). Approving the treatment variance sought by the Petitioner therefore complies with the mandate of the relevant regulation and RCRA, that compliance with the proposed treatment variance "is sufficient to minimize threats to human health and the environment posed by the land disposal of the [Subject Waste]." 40 C.F.R. § 268.44(m); 62 Fed. Reg. at 64509 (see also 64506); RCRA §3004(m)(1), 42 U.S.C. §6924(m)(1).

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[3] For example, the Army evaluated the viability of leaving the tarry residue in place in the *Draft Feasibility Study for Operable Unit 1*.

11. Expiration Date

The LDR treatment variance approved herein shall expire upon completion of the treatment and disposal of the Building 1 Remediation Wastes described in Section 5 of this document.

APPROVED:

Jeff Scott
Director, Waste Management Division
U.S. EPA, Region IX

9/27/02
Date

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

July 1, 2003

Roger Caswell, P.E.
BRAC Environmental Coordinator (BEC)
Oakland Base Transition Office
2475D W. 12th Street
Oakland, California 94607

Andrew Clough, R.G.
FOSET Environmental Manager
Oakland Base Reuse Authority
700 Murmansk Street, Suite 3
Oakland, California 94607

RE: **Amendment 1**
Site-Specific Land Disposal Restriction
Treatment Variance
Former Oakland Army Base
Oakland, California

Dear Mr. Caswell and Mr. Clough:

Enclosed please find a signed copy of Amendment 1 to the site-specific land disposal restriction (LDR) treatment variance for remediation waste at the former oil reclaiming plant, building 1 area, at the former Oakland Army Base in Oakland, California. This amendment revokes Section 2 of the original variance (signed September 27, 2002) and replaces it with language that defines the alternative treatment standard for lead contamination in the remediation waste from this site.

We determined the alternative treatment standard for lead after reviewing the results of the treatability study for remediation waste from this site (report titled "Summary of Treatability study Results, Former ORP/Building 1 Area, Oakland Army Base, Oakland, California" dated April 17, 2003). The alternative standard requires that the remediation waste be solidified/stabilized to: reduce mobility of lead and other underlying hazardous constituents; neutralize the waste to a pH of greater than 4; and decrease the percent moisture to less than 50% by weight. This standard requires that leachable lead be reduced by 77% capped by a result of 5 mg/L as measured via the Toxicity Characteristic Leaching Procedure (TCLP).

Please be aware that this amendment in no way alters any of the specific conditions that are detailed in the original LDR Variance.

We look forward to working with you to complete remediation of this site. If you have any questions, please feel free to contact me at 415-972-3291 or nelson.cheryl@epa.gov.

Sincerely,

Cheryl Lee Nelson

Cheryl Lee Nelson, R.E.A.
Senior Regulatory Advisor

Attachment: Amendment 1
Site-Specific Treatment Variance
From Land Disposal Restriction
Treatment Standards for Hazardous Wastes

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cc: Thomas W. Kalinowski, Sc.D. (w/encl.)
Erler & Kalinowski, Inc
1870 Ogden Drive
Burlingame, CA 94010

Mr. Ed Nieto (w/ encl.)
Hazardous Waste Management Program
Department of Toxic Substances Control
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Sacramento, CA 95812-1005

Mr. Henry Wong (w/encl.)
Remedial Project Manager
Department of Toxic Substances Control
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Ms. Elizabeth Lake, Esq. (w/encl.)
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San Francisco, CA 94104-1251

Mr. Donald Patterson, Esq. (w/encl.)
Beveridge & Diamond
1350 "I" Street, Suite 700
Washington, DC 20005

AMENDMENT 1
SITE-SPECIFIC TREATMENT VARIANCE
FROM LAND DISPOSAL RESTRICTION
TREATMENT STANDARDS FOR HAZARDOUS WASTES
40 CFR § 268.44 (h)

Petitioner:	Department of the Army
Facility:	Oakland Army Base
Facility Location:	Building 1, between Alaska and Bataan Streets at Maritime Street on the former Oakland Army Base, Oakland, California.
Petitioner Representative:	Mr. Roger Caswell
Title:	BRAC Environmental Coordinator Department of the Army Military Traffic Management Command 2475D W. 12th Street Oakland Army Base Oakland, CA 94607-5000
Phone:	(510) 466-2058
EPA Contact:	Jim Sullivan
Title:	Environmental Engineer
Phone:	(415) 972-3309
Date of Petition:	July 15, 2002
Date of Original LDR Variance:	September 27, 2002

Subject of the Petition: Building 1 Remediation Wastes, which consist of soil inseparably commingled with tarry residue generated by a former waste oil reclaiming plant which operated at the Oakland Army Base ("OARB") from the 1920s until 1941. The estimated inventory of Building 1 Remediation Wastes subject to this petition is 6,000 cubic yards.

Summary of the Petition: The Building 1 Remediation Wastes, which are the subject of this Petition, are expected to display the D008 toxicity characteristic for lead and/or the D002 corrosivity characteristic. The Petitioner also believes that the Building 1 Remediation Wastes will also contain polycyclic aromatic hydrocarbons ("PAHs"), polychlorinated dibenzodioxins ("PCDDs"), polychlorinated dibenzofurans ("PCDFs"), and polychlorinated biphenyls ("PCBs"), which constitute underlying hazardous constituents ("UHCs") under the RCRA Land Disposal Restrictions ("LDR") program. The Petitioner seeks a one-time, site-specific variance from various alternative LDR treatment standards for soil, pursuant to 40 C.F.R. § 268.44(h).

1. Alternate Treatment Standard

Section 2 of the September 27, 2002 approved LDR Variance is hereby revoked and replaced with the following:

Solidification/stabilization technology will be applied to Building 1 Remediation Wastes to reduce the mobility of lead and other underlying hazardous constituents present in the wastes. The solidification/stabilization agent will also neutralize the Building 1 Remediation Wastes' acidic and remove the liquid properties. After treatment, the Building 1 Remediation Wastes will have a pH of greater than 4 and a percent moisture less than 50 percent by weight.

Lead has been selected as the indicator compound to determine adequate treatment of the Building 1 Remediation Wastes. The selected site-specific alternative treatment standard is a 77% reduction in leachable lead, capped by a result of 5 mg/L (or less) as measured via the Toxicity Characteristic Leaching Procedure ("TCLP"). The percent reduction is based upon the lowest percent reduction of leachable lead document in a treatability study as a result of the most effective solidification/stabilization technology tested, a factor of safety intended to account for the inevitable variability encountered during remedial work and implementability.

Performance will be determined by measuring the concentration of TCLP lead before and after applying solidification/stabilization technology to the Building 1 Remediation Wastes. The confirmation sampling frequency is anticipated to consist of one representative soil sample composited from a minimum of four individual samples collected from each 200 cubic yards of soil to be treated. The actual confirmation sampling frequency may be modified based upon the level and consistency of performance observed in the solidification/stabilization of Building 1 Remediation Wastes during remedial work.

2. Authority Of The Director Of The Waste Management Division Of EPA Region IX To Approve Or Deny The Petition For A Variance Pursuant To 40 C.F.R. 268.44(h)

The determination of the petition by the Director of the Waste Management Division of EPA, Region IX, (the Region) is in accordance with delegations 8-45-A and 8-45-B (March 24, 1997) which delegate to the Regional Administrators the authority to approve or deny applications submitted pursuant to 40 C.F.R. 268.44(h) for site-specific treatment variances from LDR treatment standards, and with delegations R9 1280.18 and R9 1280.19 (March 28, 1998) which further delegate the authority from the Regional Administrator to the Director of the Waste Management Division.

3. Effective Date of Approval of the Amendment

The effective date of the LDR treatment variance and this amendment is the date that the Director of the Waste Management Division has signed below. When final, this variance is effective under federal law. States authorized for the RCRA program can be more stringent than EPA. The Petitioner should check with the State where this waste will be disposed for any additional State requirements that may apply.

4. Expiration Date

The LDR treatment variance approved herein shall expire upon completion of the treatment and disposal of the Building 1 Remediation Wastes.

APPROVED:

Amy K. Zimpfer
Acting Director
Waste Management Division
U.S. EPA, Region IX

6/30/03
Date

APPENDIX F

TREATMENT PAD DETENTION CAPACITY

Treatment Pad Runoff Detention Capacity

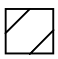
Total Volume of Detention Capacity (V_{DC}):

$V_{DC} = V_{PAD} - 7 \times V_{SP} = 91326\ ft^3 - 7x\ 2{,}773\ ft^3 = 71{,}915\ ft^3 \sim 535{,}000$ gal

Volume of the Treatment Pad

- $V_{PAD} = V_1 + V_2 = 55422\ ft^3 + 35{,}904\ ft^3 = 91326\ ft^3$

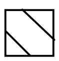
Frustum Volume of a Rectangular Pyramid:



$V_1 = h/6\ [(2A + a)B + (2a + A)b]$

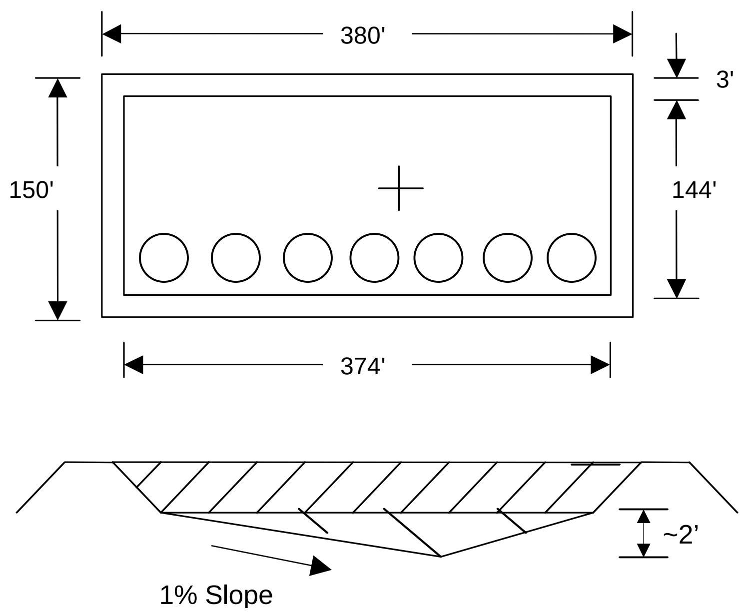
$= 1/6 \times 1' \times [(2 \times 380' + 374') \times 150' + (2 \times 374' + 380') \times 144'] = 55{,}422\ ft^3$

Volume of a Rectangular Pyramid:



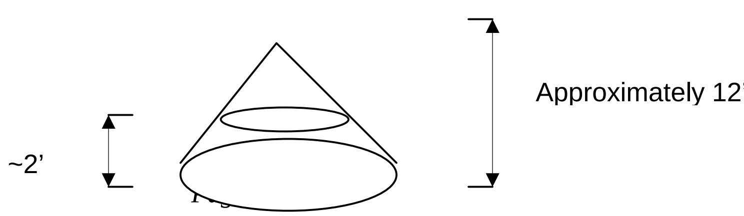
$V_2 = h/3\ ab$

$= 1/3 \times 374' \times 144' \times 2' = 35{,}904\ ft^3$



Volume of a Frustum of a Cone:

- $V_{SP} = 1/3\ \pi\ h\ (r^2 + rR + R^2) = 1/3 \times \pi \times 2' \times (20'^{\,2} + 22' \times 20' + 22'^{\,2}) = 2{,}773\ ft^3$



APPENDIX G

PUMP SPECIFICATIONS

S SERIES® WIDEBASE SUBMERSIBLE PUMPS

Open Pits and Quarries

Whether sitting on the soft, murky bottom of a cofferdam, or churning away deep inside a strip mine or quarry, Gorman-Rupp Widebase submersible pumps tackle the big jobs. Where large solids are not a problem, these versatile models offer high-head, high-volume operation and stand up to the abuses of the worst conditions. Whatever the application – general construction, strip mining, tunnel work or general-purpose – Gorman-Rupp Widebase pumps are built to operate quietly, effectively and safely.

The wide, solid base helps prevent pumps from turning into the ground or pumping into a hole. The rugged impeller provides many trouble-free years of service. The motor operates in an oil-filled cavity, which is cooled by the water being pumped to prevent overheating. Double seals provide solid protection against pump failure and ensure years of dependable service.

GORMAN-RUPP PUMPS
COUNT ON IT

ENGINEERED FOR RELIABLE, ECONOMICAL PERFORMANCE

Gorman-Rupp's submersible pump designs are engineered for maximum dependability. One moving part and three wearing surfaces translate into a simple design that offers more rugged durability and pump life without costly maintenance.

RUGGED IMPELLER HANDLES TOUGH ABRASIVES

Abrasion-resistant ductile iron and manganese bronze impellers stand up to sand, gravel, concrete powder and other abrasive construction materials. The fully shrouded impeller back reduces seal pressure and helps prevent foreign material from entering the seal cavity, extending seal life and, in turn, the operational life of the pump. Optional CD4MCu impellers are available for extremely corrosive and abrasive applications.

CORROSION-RESISTANT STAINLESS STEEL SHAFT AND HARDWARE

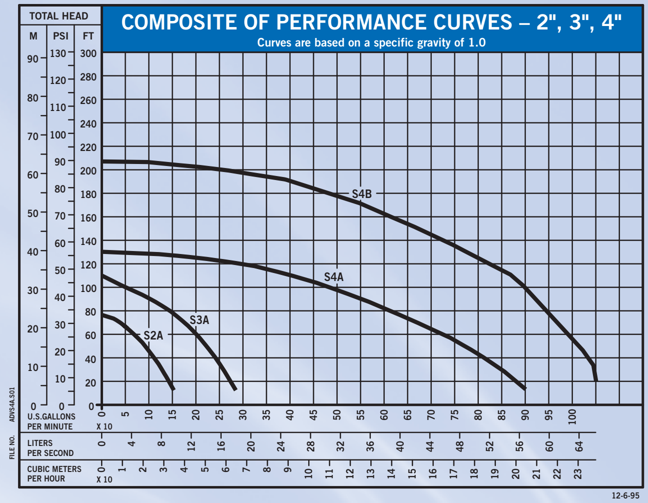
Pump rotor shafts and internal nuts and bolts coming in contact with fluids are made of stainless steel to avoid corrosion and pitting. CD4MCu configurations are also available.

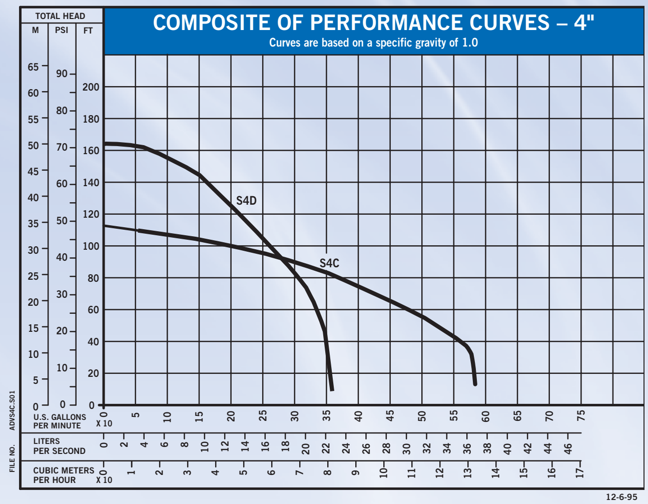
OIL-FILLED MOTOR CAVITY KEEPS MOTOR COOL

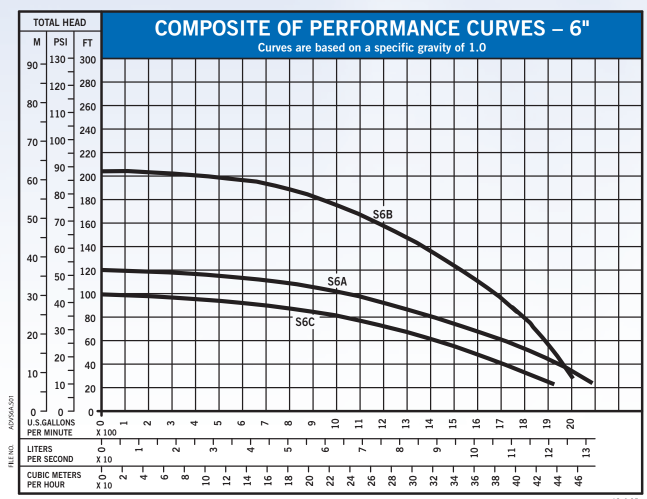
When a Gorman-Rupp submersible starts pumping, a flow of water is established between the inner and outer walls of the motor housing, cooling the oil that in turn cools the motor and prevents overheating.

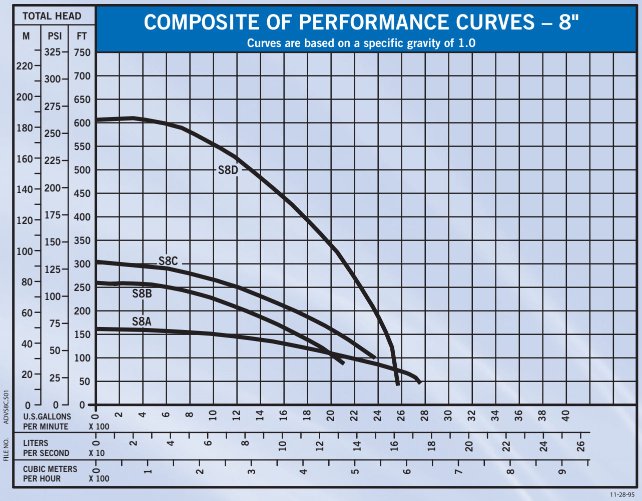
DUAL SEALS, DOUBLE PROTECTION

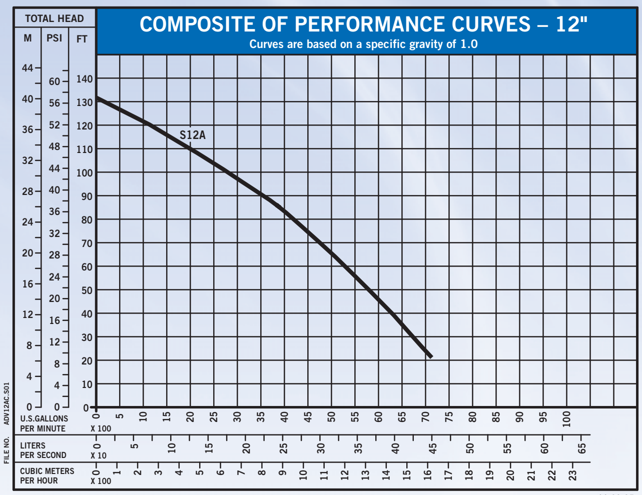
A primary seal keeps dirty water in the pump end and prevents contamination of the oil cavity; a second "fail safe" seal provides extra protection against the possibility of damage to the motor. Positive oil lubrication enables the pump to run dry without seal damage.











WIDEBASE SUBMERSIBLE DATA

MODEL	DISCHARGE	HEIGHT	DIAMETER	MAX. SOLIDS	POWER	HERTZ	SPEED	PHASE	VOLTAGE	CABLE SIZE
S2A1	2"	23.13"	11.19"	0.31"	2 HP	60	3450 RPM	1	115/230	#10, #14
S3A1	3"	28.54"	14.19"	0.38"	5 HP	60	3450 RPM	1, 3	230/460/575	#10
S4A1	4"	43.06"	23.25"	0.62"	25 HP	60	1750 RPM	3	460/575	#6
S4B1, S4B18*	4"	46.45"	28.00"	0.62"	50 HP	60	1750 RPM	3	460/575	#6
S6C1	6"	47.00"	23.25"	0.62"	35 HP	60	1750 RPM	3	460/575	#6
S6A1	6"	57.44"	28.00"	1.00"	60 HP	60	1750 RPM	3	460/575	#6
S6B1, S6B18*	6"	57.44"	28.00"	1.00"	95 HP	60	1750 RPM	3	460/575	#2
S8A1, S8A18*	8"	57.44"	28.00"	1.00"	95 HP	60	1750 RPM	3	460/575	#2
S8B1	8"	60.20"	31.25"	0.62"	100 HP	60	1750 RPM	3	460/575	#1
S8C1, S8C18*	8"	60.20"	31.25"	0.62"	140 HP	60	1750 RPM	3	460/575	#2/0, #1
S8D1	8"	65.42"	33.50"	0.62"	275 HP	60	1750 RPM	3	460/575	#2/0
S12A1	12"	54.78"	31.25"	1.00"	140 HP	60	1750 RPM	3	460/575	#2/0

*Stainless steel fitted
This chart represents only a small cross-section of models available. Specifications are subject to change. Consult your Gorman-Rupp distributor for detailed information.

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November 14, 2005 *Project No. 1147.01*

Mr. Andrew Clough
Environmental Manager
Oakland Base Reuse Authority
700 Murmansk Street, Suite 3
Oakland, California 94607

Re: Response to DTSC's November 8, 2005 Comment on
Soil Treatment Process Plan, Former ORP/Building 1 Area
Former Oakland Army Base—Economic Development Conveyance Area
Oakland, California

Dear Mr. Clough:

On behalf of the Oakland Base Reuse Authority (OBRA), Northgate Environmental Management, Inc., (Northgate) has prepared this response to an additional comment from Henry Wong, Remedial Project Manager, Department of Toxic Substances Control (DTSC), transmitted via email on November 8, 2005. DTSC has requested OBRA to address the following comment from Mark Berscheid, of the DTSC Engineering Services Unit:

> ***The Engineering Services Unit (ESU) requests the final plan contain the documentation in the form of drawings and/or document text to define the actions necessary to prevent the type of mixer motion (i.e., dedicated pads, mechanical machine tie down) causing treatment pad penetration.***

Response to Comment:

We understand that the above comment stems from DTSC's review of Pacific States' work on the Baylands Recovery Project (Baylands). The Baylands project was very similar to the proposed remediation at the Former Building 1/ORP Site (the Site), including the construction of a similar treatment pad, and use of a mobile soil mixing machine to treat wastes. This machine has a control system that maintains soil mixing depth and travel speed. The soil mixer is designed to operate at a constant depth. During the Baylands project, the mixer ran over a few large, hard pieces of material causing it to tilt and cut into the asphalt concrete surface of the treatment pad. We understand that damage to the pad was limited to a few locations, and the underlying membrane was not affected.

Given the mobile operation of the soil mixer, it is not feasible to control the mixing depth with dedicated pads or tie-down devices. However, Section 2.9 of the STPP includes pre-treatment procedures to remove debris and separate or crush material larger than 4 inches in any dimension. This step will allow the soil mixer to maintain a constant mixing depth, substantially reducing or eliminating the potential for damage to the pad. In accordance with Section 2.1 of the STPP, the treatment pad surface will be monitored for potential breaches after each batch is treated, and will be maintained as necessary to contain the Building 1 Remediation Waste. If the pad is damaged during operation of the soil mixer, it will be repaired by hot asphalt patching in combination with spray binders.

If you should have any questions regarding our response to DTSC's comments on the STPP, please contact me at (510) 839-0415. We look forward to your review and approval of this document.

Sincerely,
Northgate Environmental Management, Inc.

Alan L Leavitt

Alan Leavitt, P.E.
Principal

Distribution:

Henry Wong, DTSC
Mark Berscheid, DTSC
Ms. Diane Heinze, Port of Oakland
Ms. Xuan-Mai Tran, US EPA
Mr. Devender Narala, RWQCB
Mr. Jim Carolan, Geomatrix
Mr. Michael T. Steiger, EKI
Mr. Roger Caswell, BRAC Environmental Coordinator

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November 14, 2005 *Project No. 1147.01*

Mr. Andrew Clough
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700 Murmansk Street, Suite 3
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Re: Response to DTSC's November 10, 2005 Comments on
Soil Treatment Process Plan, Former ORP/Building 1 Area
Former Oakland Army Base—Economic Development Conveyance Area
Oakland, California

Dear Mr. Clough:

On behalf of the Oakland Base Reuse Authority (OBRA), Northgate Environmental Management, Inc., (Northgate) has prepared these comments in response to the above referenced email communication from Henry Wong, Remedial Project Manager, Office of Military Facilities, Department of Toxic Substances Control (DTSC), dated November 10, 2005.

1. Section 2.2 and RTC #18: The STPP states that a front loader will remain on the treatment pad for spreading stockpiled Building 1 Remediation waste into 18-in thick layer. Please discuss the procedures for a front loader to spread the waste without tracking any waste outside of the treatment pad.

<u>Response to Comment No. 1</u>

The general operating procedure will be to "back-drag" the loader bucket. This process involves spreading out the Building 1 Remediation Waste by operating the loader in a backwards direction, progressing from relative high points to low points, to ultimately form an 18-inch thick layer for treatment. Near the edges of the treatment pad, the operator will turn around the loader to approach the bermed perimeter in a forward direction. In this way, the operator can scoop up material and deposit it close to the berm. The operator will resume back-dragging the bucket either parallel to the bermed edge or towards the interior of the pad, as necessary to form an 18-inch layer. Using the above method will allow the front loader to remain on the pad at all times while spreading the soil. Section 2.2 of the STPP has been revised to note that back-dragging will be used, as necessary to keep the front loader on the treatment pad.

2. ***Section 2.5, et al. and RTC #24: This comment does not apply to Building 1 Area's RDIP/SAP/STPP. DTSC's concurrence with the sampling frequency (i.e., one 3-point composite sample per 600 cubic yards of Overburden) is for the Building 1 Area only. To determine whether soils from all RMP Locations and RAP Sites other than the Building 1 Area are suitable for on-site reuse, the sampling frequency shall be one 4-point composite soil sample for each 200 cubic yard batch of stockpiled soil.***

Response to Comment No. 2

This comment does not require any change to the STPPP.

If you should have any questions regarding our response to DTSC’s comments on the STPP, please contact me at (510) 839-0415. We look forward to your review and approval of this document.

Sincerely,
Northgate Environmental Management, Inc.

Alan L Leavitt

Alan Leavitt, P.E.
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November 14, 2005 *Project No. 1147.01*

Mr. Andrew Clough
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Re: Response to US EPA's November 10, 2005 Comments
Soil Treatment Process Plan, Former ORP/Building 1 Area
Former Oakland Army Base—Economic Development Conveyance Area
Oakland, California

Dear Mr. Clough:

On behalf of the Oakland Base Reuse Authority (OBRA), Northgate Environmental Management, Inc., (Northgate) has prepared these comments in response to the above referenced email communication to DTSC from Xuan-Mai Tran, Remedial Project Manager, Federal Facility and Site Cleanup Brach, United States Environmental Protection Agency Region IX, dated November 10, 2005.

We have reproduced US EPA's comments below, followed by our responses.

1. The response to EPA general comment number 1 refers to the RDIP SAP for information on the confirmation sampling. However, the STPP does not include a reference to the RDIP SAP for this information. The STPP would be more useful as a stand-alone document with this additional reference.

Response to Comment No. 1.

We have revised Section 2.5 of the STPP to indicate that confirmation samples will be collected from the bottom and sidewalls of the excavation in accordance with the SAP, and included a citation for the SAP.

2. ***The response to EPA specific comment number 1 refers to the Health and Safety Plan (HSP) for the list of chemicals of concern (COCs) that may be encountered during remediation, but the HSP is not referenced in the STPP when the COCs are discussed. The STPP would be more useful as a stand-alone document with this additional reference.***

Response to Comment No. 2.

We have revised Section 1.3 of the STPP to indicate that the list of COCs is provided in Section 2.2 of the Site Specific Health and Safety Plan (SSHSP), and included a citation for the SSHSP.

If you should have any questions regarding Northgate's response to U.S. EPA's comments on the Plan, please contact me at (510) 839-0415.

Sincerely,
Northgate Environmental Management, Inc.

Alan L Leavitt

Alan Leavitt, P.E.
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